THE GLASS INDUSTRY

VOLUME 24, NUMBER 2, FEBRUARY, 1943

ZINC OXIDE IN GLASS

By NORBERT J. KREIDL*

PART I

Zinc Glasses Old and New

Zinc crystal was the name of a new variety of fine flint glass which made its sensational appearance at the London Exposition of 1851. The inventor, Maës, expected nothing less than the elimination of the expensive crystal glass by this new type of glass. Two kinds of colorless and brilliant glass had been used by the refined public up to this time: the English crystal, with its high lead content, soft towards the cutting wheel, brilliant, and heavy, with its characteristic ring; and the Bohemian crystal with its high potash content — hard, suitable for engraving and etching, less costly but not as brilliant with scarcely any typical ring. Contrary to Maës' hopes, these classical crystal glasses remained dominant. In fact, no new type of glass surpassing their excellent quality or successfully competitive in production cost was ever discovered; and, only in our present days are lead and potash crystal glasses gradually replaced, even in more ambitious surroundings, by their democratic competitor, the old soda-lime glass, in new make-up; made from magnetically and chemically cleaned selected raw materials, ably decolorized, machine-shaped to graceful simplicity, glossy from well-treated molds. . . .

Zinc crystal glass was beautiful, had excellent melting, working, grinding, and cutting properties, but there was no distinctive difference, neither in quality nor in price to justify its commercial manufacture in the place of lead glass. At the present time, with so many special zinc glasses existing, it seems appropriate to remind ourselves of the composition of this first high zinc glass.

TABLE I
Composition of Zinc Crystal Glass (1851)

SiO_2	56
B_2O_3	7
K_2O	17
CaO	2
PbO	4
ZnO	**14**

Soon afterwards, in Pennsylvania, Wetherill[1] patented a lime free glass of very high zinc oxide content, the yellowish hue of which was compensated by nickel oxide.

TABLE II
Wetherill's Zinc Glass

Sand	60
Soda	20
Zinc Oxide	**40**
Arsenic	0.1
Manganese	0.06
Nickel Oxide	0.01

As in the case of the application of most of the other elements, the investigation of optical glasses prepared the ground work for a much more extended use of zinc oxide. Many specific properties are imparted by zinc oxide. In many cases the effect appeared to be unique, and had remained unexplained. A list of specialized zinc glasses will show an unusual variety of purposes. At the present time, a survey of these purposes and an attempt to analyze underlying principles are more justified than ever. Now we are desirous to obtain all possible information on the function of zinc oxide with the aim to replace it intelligently. Hitherto, the users of zinc oxide, who are manufacturers of specialties were not too much concerned with potential replacement materials. Whatever appeared closest in effect was still so remote that considerations of substitutions were dismissed. During the present emergency necessity has caused a changed attitude. The producers of zinc oxide have not been too interested in this development; the ceramic industry, being far from enjoying a high priority rating, is supposed to come back one hundred per cent when zinc oxide again will have to look for a market instead of being allocated.

In this survey an attempt will be made to summarize the evidence of the effect of zinc oxide in the following typical applications.

TABLE III
Applications of ZnO to Glass

1. Apparatus Glass, (Laboratory Ware)
2. Glasses of Specific Thermal Requirements (Thermometer water gauge)
3. Compound Glass
4. Stabilized Phosphate Glasses, UV-Transmitting Glasses
5. Zinc Crown

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6. Barium Crown and Flin
7. Zinc Borate Glass
8. Minor Additions to Tank Glass
9. Lead Substitute
10. Effect of ZnO on Sulfide and Selenium Glasses
11. Other Colored Glasses
12. Fluorine Opal Glass
13. Glazes and Enamels Opacified with TiO_2 and ZrO_2
14. Crystalline Glazes, Devitrification
15. Electrical Properties
16. Foam Glass

(1) Apparatus Glass

(a) Jena Glass

The main properties of good laboratory ware are resistance towards chemical attack and towards thermal shock. Both properties are not simple functions of composition; the first depends on the details of the reactions of the glass constituents with the attacking media and the solubility of the reaction products; the second depends on low thermal expansion, and low specific heat in combination with satisfactory mechanical strength. Nowadays it seems natural to work with special glassware in the laboratory; in my college years we were not as fortunate. We did not have to buy our own glassware but were required to replace broken pieces of the kind of ware the school carried in stock. It was the experience of everyone of us that this glassware was suffering from thermal shock on what we thought mild heating and it proved economical to buy our private stock of imported apparatus glass. This imported glass was the famous Jena Geraeteglas, developed from Schott's original borosilicate glasses.

The borosilicate glasses had represented the basic solution of the problem of a durable, heat resisting glass. Their discovery was soon followed by that of some glasses containing zinc oxide instead of, or together with boric acid. The glass 15 III,[2] melted in 1889, will be given in Table IV. This experimental glass preceded a family of compositions containing zinc which were to be used for various specific purposes requiring chemical and thermal resistivity.[3]

TABLE IV
Zinc Containing Jena Glass (1889)
Glass No. 15 III

Al_2O_3*	2.0
B_2O_3	...
SiO_2	67.0
K_2O	9.0
Na_2O	8.0
ZnO	**7.0**
CaO	7.0

In 1910 a Jena glass was composed as shown in Table V[3].

TABLE V
Zinc Containing Jena Glass (1910)

Al_2O_3	2.4
B_2O_3	4
SiO_2	66.4
Na_2O	15.6
ZnO	**6.2**
MgO	5.2

The newer glass, 1447 III, is shown in Table VI, where another hard Jena apparatus glass [4] is also given.

(b) Other Laboratory Glassware

The Jena glasses were followed by similar glasses in the entire glass making world, especially after 1915. Examples of French, Italian, and English apparatus glasses are given in Table VII.

TABLE VI
Other Zinc Containing Jena Glasses

	1447 III	Hard Apparatus
Al_2O_3	4.5	5.2
B_2O_3	10.9	2.5
SiO_2	64.7	65.3
K_2O	.4	2.3
Na_2O	7.6	12.5
ZnO	**10.9**	**5.1**
MgO	.7	....
CaO	....	6.9
MnO	....	.4

TABLE VII
Foreign Apparatus Glass

	COUNTRY OF ORIGIN				
	France	France	Italy	England[8]	Bulbs of special resistivity (over-sea transportation)
	TYPE AND DATE				
	Miner's Lamp[5] 1915	1917[6]	(Murano)[7] 1922	....	
Al_2O_3	6.9	1.	6.3	9.5	....
B_2O_3	3.9	4.	10.5	8.7	....
SiO_2	51.3	69.4	66.	63.5	64.3
K_2O	2.7	5.9	....	....	.4
Na_2O	....	6.5	6.	10.9	13.3
PbO	27.5	....	....	....	15.1
ZnO	7.2	7.4	10.	7.5	2.3
Sb_2O_3	.5	....	....	....	....
CaO	....	5.8	1.	....	....
BaO	....	....	....	....	4.3

Representative American zinc containing apparatus glassware is exemplified by compositions, the magnesia content of which is typical. (Table VIII)

TABLE VIII
American Apparatus Glass

	COUNTRY OF ORIGIN		
	U.S.A.	U.S.A.	U.S.A.
	.....	MAKER McBeth Evans	Fry[11]
		TYPE AND DATE	
	Bulb[9] Parts	Tumbler[10]	
	....	....	1918
Al_2O_3	2.5	1.4	3.1
B_2O_3	....	3.6	8.
SiO_2	58.5	73.	68.6
K_2O	5.	.3	1.3
Na_2O	8.4	10.8	10.
ZnO	**5.5**	**5.6**	**3.6**
Sb_2O_3	....	.6	....
CaO	.5	.7	....
MgO	.2	4.3	2.6

(c) The Influence of Zinc Oxide on Viscosity.

In the development of laboratory glass compositions the ions of lower valency are the least suitable constituents. Due to their looser bonds with the oxygen network of the glass they are inclined to react more easily with the attacking chemical, for instance, with water. Especially a high alkali content has to be avoided. In regular soda lime glasses this would lead to exceedingly high fusion temperatures; in the borosilicate glasses, which melt with comparative ease, B_2O_3 represents the desirable non-alkaline flux. Zinc oxide contributes to the properties of a meltable and resistant glass, because it resembles SiO_2 in its effect on restivity, while it fluxes SiO_2 to a certain extent. The influence of zinc oxide on the viscosity in areas determining melting and working behavior is quite involved. For the summarizing purpose of this paper the experience on the change of viscosity caused by the

*In the tables of this paper Fe_2O_3 is included in the Al_2O_3 content.

addition of less than 5 per cent zinc oxide may be abstracted as follows:

(aa) The replacement of alkali by zinc oxide increases the viscosity in all temperature ranges[11]. Zinc oxide is a much less efficient flux than alkali (Fig. 1) and barium (Fig. 2).

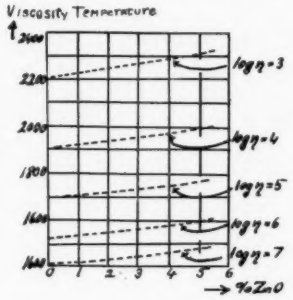


Fig. 1. Effect of Substituting Z n o for Na_2 on Viscosity (Owens-Illinois).

(bb) At high viscosities, that is in the low temperature range, the viscosity of calcium and of zinc glasses is similar; but at low viscosities, that is in the high temperature or melting range, the zinc glass is harder to melt[11, 12]. (Fig. 3) In other words the zinc glass is

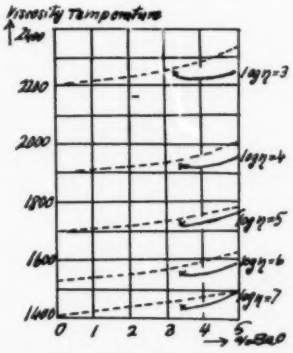


Fig. 2. Effect of Substituting B a O for Na_2O on Viscosity (Owens-Illinois).

somewhat harder but sweeter than the lime glass. Occasionally a similar effect was reported even in the case of the replacement of alkali[12]. In Fig. 4, comparative data on barium are reproduced.

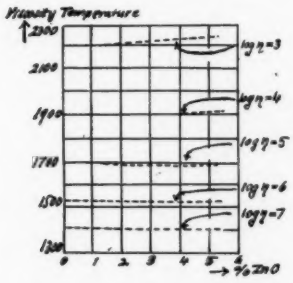


Fig. 3. Effect of Substituting Z n O for CaO.MgO on Viscosity.

(cc) With respect to sweetness, zinc oxide exerts an influence between that of calcium and barium oxide[11]. (Fig. Ic, Id) Barium oxide sweetens the glass still more than zinc oxide because in the low temperature range the barium glass is even less viscous than the lime glass. The similar position of strontium between calcium and barium makes strontium oxide an important potential constituent of glasses and glazes where the action of zinc oxide is to be approximated.

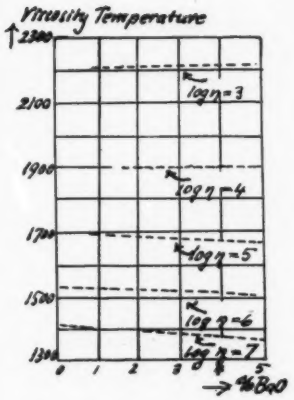


Fig. 4. Effect of Substituting B a O for CaO.MgO on Viscosity (Owens-Illinois).

(dd) When substituting for silica, zinc oxide decreases viscosity less than other divalent oxides[11] (Fig. 5 and 6). The decrease is not only smaller, but also less outspoken at low temperatures than in the case of barium.

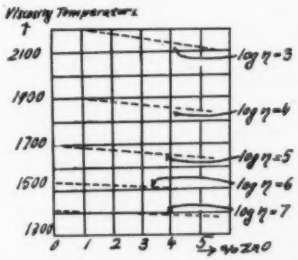


Fig. 5. Effect of Substituting Z n O for SiO_2 on Viscosity (Owens-Illinois).

In all these substitutions the effect of zinc oxide resembles that of Fe_2O_3, as published in a more recent section of the valuable research series of the staff of the Owens-Illinois Glass Company[13]. More particularly it is interesting to note how both ZnO and Fe_2O_3 increase viscosity at high temperature and decrease it at low temperature. We shall see that this comparison may be correlated with the possibility for Fe_2O_3 to participate in the glass structure proper, that is to function like SiO_2, at elevated temperatures.

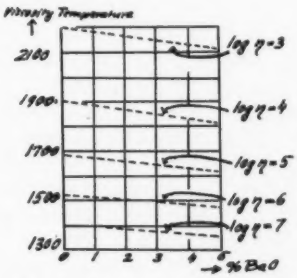


Fig. 6. Effect of Substituting B a O for SiO_2 on Viscosity (Owens-Illinois).

In the laboratory of the author the softening points of simple silicate glasses could not be lowered to any considerable extent, even where more than 5 per cent SiO_2 was replaced by ZnO. BaO, however, caused a strong effect.

We can derive a simplified conclusion from the various influences on viscosity when zinc oxide replaces various constituents: glass of a viscosity similar to that of soda lime glass can be obtained by decreasing both lime and silica at the expense of zinc oxide.

The question is, whether the decrease of silica will impair chemical resistivity as in soda-lime glasses, or not. In

borosilicate glasses we have seen that a decreased silica content is not detrimental.

The question also can be asked like this: is zinc oxide more similar to silica with respect to resistivity than other divalent oxides? With respect to viscosity there is certainly such a trend.

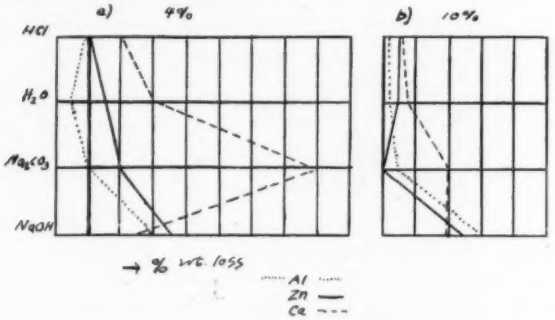


Fig. 7. Resistivity of Glasses Containing (a) 4 per cent ZnO, CaO, Al_2O_3 (b) 10 per cent ZnO, CaO, Al_2O_3 towards media of different acidity (From data of Dimbleby and Turner).

The answer, given by the existent laboratory glasses of glasshouse practice, appears to be affirmative. It is interesting to see to what extent this is true for more fundamental glasses of the $Na_2O - CaO - SiO_2$ system, where the replacement by zinc oxide is not as much complicated by additional constituents such as boric acid.

(d) The Influence of ZnO on Chemical Resistivity.

In order to demonstrate the fundamental effect of zinc oxide on the resistivity of simple sodium silicate glasses, I have arranged some values obtained by Dimbleby and Turner[14] in a very schematical way. These authors compared the chemical resistivities of glasses 6 SiO_2. (2-x) Na_2O. x R_mO_n, for R_mO_n= CaO, Al_2O_3, BaO, MgO, ZnO, ZrO_2 and TiO_2, towards water, sodium carbonate, sodium hydroxide, and hydrochloric acid. Since the favorable effect of calcium and aluminum is well known to the glass technologist, this schematical arrangement compares only lime, alumina, and zinc oxide. I selected one small but equal addition of these three oxides for a characteristic value of resistivity expressed in terms of weight loss and grouped the four data in the order of the acidity of these reagents. In this way Fig. 7[a] contains 12 data of resistivity which show the order of efficiency of Ca, Zn, and Al at one typical concentration (4 per cent) towards four media of increasing acidity.

If the absolute values of resistivity are neglected and the mere order of efficiency shall be demonstrated, the following chart will be found illustrative. (Fig. 8[a])

It becomes evident that in relatively small substitutions zinc oxide is similar to alumina and superior to calcium oxide. It is more efficient in comparison to the usual

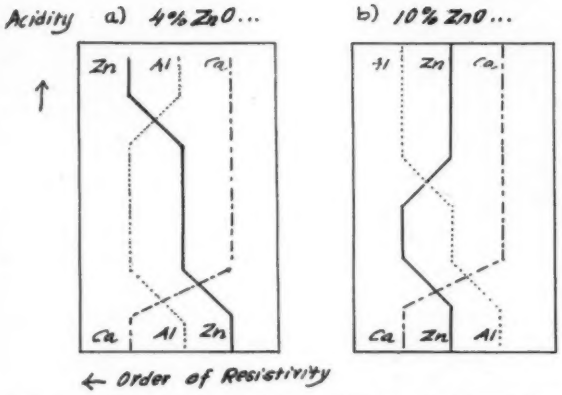


Fig. 8. Chart of the Order of Efficiency in Improving Chemical Resistivity for ZnO, Al_2O_3 and CaO. (a) Concentration of compared oxides 4 per cent. (b) Concentration of compared oxides 10 per cent. (From data of Dimbleby and Turner.)

stabilizers calcium oxide and alumina the more acidic the solution is. Only towards sodium hydroxide the influence of the more basic calcium oxide is slightly superior to that of zinc oxide and alumina. Figure 7[b] and 8[b] give the same arrangement for a concentration of 10 per cent. Now the action of alumina and zinc oxide is still more similar, the latter being superior in neutral solutions, and lime again is inferior except towards sodium hydroxide.

Summarizing, it may be said that unlike lime and more like alumina zinc oxide behaves like a strongly stabilizing oxide; the efficiency is emphasized in acidic media, sometimes even more than in the case of alumina.

In accordance with these results Enns[15] had found that replacement of alumina by zinc oxide causes only a very slight decrease of resistivity, with no optimum formed by the addition of both oxides. It should be added, that the influence on other properties makes the simultaneous use of both oxides advisable.

Fig. 9. Effect of Substituting ZnO for SiO_2, CaO.MgO, Na_2O on Acid Durability (Owens-Illinois).

Enns had also examined the effect of 1 per cent of divalent oxides replacing silica and not soda as in the foremention work of Dimbleby and Turner. Improvements were obtained throughout. Water was the attacking

(*Continued on page 84*)

TABLE X

Fluorescence of Mn++ in Phosphate Glasses Containing Various Divalent Elements

Amount of Divalent Phosphate (Other constituents as in Table IX)	$Ba(PO_3)_2$	$Sr(PO_3)_2$	$Ca(PO_3)_2$	$Mg(PO_3)_2$	$Zn(PO_3)_2$
5	Red	Red	Red orange	Red	Red
30	Red	Red	Orange	Orange	Orange
40	Orange red	Orange red	yellow orange	greenish yellow	greenish yellow

ACCELERATED MELTING OF GLASS BATCH

By A. E. BADGER and L. G. FARBER†

In melting glass on the commercial scale it is considered advisable to mix the raw materials well and to prevent any subsequent segregation which sometimes occurs in the mixed batch. The question arises, however, whether a certain glass composition may conceivably be melted more rapidly from a mixture of batches than from the single well-mixed batch. For example, glass *P* in Figure 1 represents a common soda-lime-silica glass composition (16 Na_2O, 12 CaO, 72 SiO_2). This glass may be formed by melting a batch corresponding to *F* or by melting mixtures of two or more batches. Thus, batch *E* may be mixed in proper proportion with batch *A* to produce glass *P*. From the thermodynamic standpoint, the quantities of heat necessary to produce glass *P* by these two methods would be the same, but the rates of reaction may be different.* Also, the rate at which the glass fines may be changed markedly. The fining rate depends mainly on the viscosity of the glass and on the size of the seeds. From the viscosity viewpoint there is little encouragement in trying to produce faster melting batches by the above method, since the final glass composition usually has a lower viscosity than that of the component glasses. However, the size of the seeds may be influenced markedly by the rate of reaction and larger seeds would result in more rapid fining.

Fig. 1

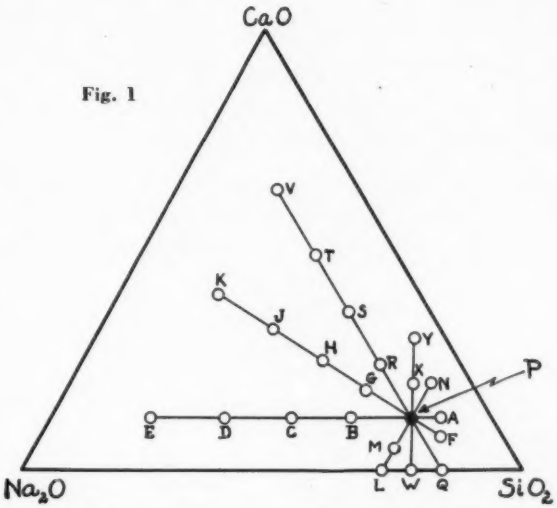
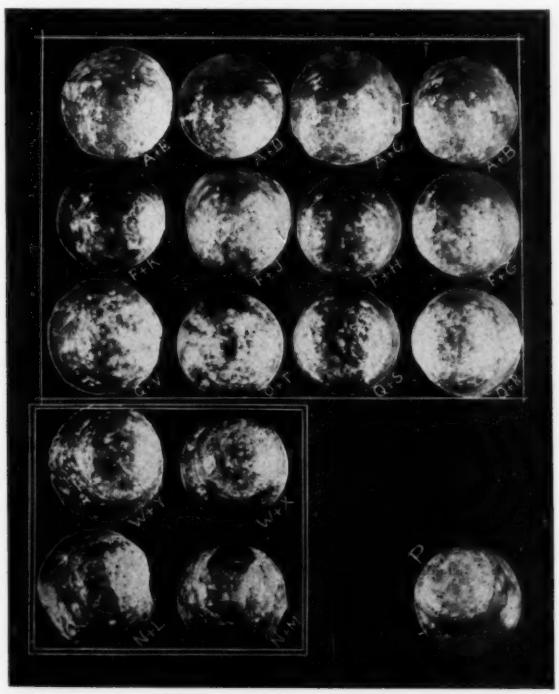


Fig. 1. Triaxial diagram showing amounts of soda, lime, and silica in various briquetts. These briquetts were mixed in proper proportions so that glass composition *P* was produced in all cases. (Composition of glass *P* is 16 Na_2O, 12 CaO, 72 SiO_2).

*For an instructive article on melting rates, see "Melting Rate of Soda-lime-silica Glasses as Influenced by Composition and the Effect of Minor Constituents," by J. C. Potts, J. Am. Ceram. Soc. 24 4350 (1941).

†Department of Ceramic Engineering, Engineering Experiment Station, University of Illinois.

Fig. 2. Photograph of results of melts in platinum crucibles. Batches in single borderline were inferior to ordinary batch *P*. Batches in double borderline were nearer to complete melting and fining than was batch *P*.



A series of preliminary melting experiments was devised to determine whether additional work on this subject might be advisable. It was decided to use a melting temperature of about 1400° C, since this temperature is close to commercial practice and could be obtained easily in electric furnaces in the laboratory.

The field of batches is shown in Figure 1. Sodium carbonate, calcium carbonate, and potter's flint were the batch constituents. Each batch designated by a letter was made in the form of small pellets, about $\frac{3}{32}$ inch in diameter, by mixing the batch with a small amount of water, allowing it to dry, and then passing it through a coarse screen.

Calculated amounts of these small "briquetts" were then weighed, mixed, and placed in platinum crucibles. The relative amounts of different batches were so calculated that glass *P* would be produced in all cases. The crucibles containing the batches were then placed, one by one, in a Globar electric furnace and heated for a period of five minutes at 1375° C.

Figure 2 is a photograph of the group of crucibles after completion of the tests. Glasses enclosed in the single borderline were "spotty," containing islands of unmelted batch. Glass *P* which was made from a single well-mixed batch contained these islands also, but they were more diffuse. Glasses in the double borderline were definitely in a more advanced melting stage than was glass *P*. Of the four glasses enclosed in this area, glasses $(L + N)$ and $(M + N)$ appeared the best and it was decided to make additional tests with these glass batches.

Only ten grams of glass were produced in each of the above tests since the use of platinum crucibles restricted

the weight of the glass batch. These small melts served to indicate the most promising batches to use for larger tests. For these larger tests about one pound of glass was produced. A gas-fired kiln was used to bring the empty refractory pots to a temperature of about 1450° C. The door of the kiln was then opened and the briquetted batches dumped into the pots. Heating was continued for twenty minutes and the gas then shut off, the pots being allowed to cool with the furnace. The states of melting and fining of these glasses were compared by visual examination.

Since larger batches were used in these tests, the briquettes were increased in size accordingly. These briquettes were made as previously, that is, by the addition of water with subsequent drying, but were cut into sections about $\frac{3}{8}$ inch square and $\frac{1}{8}$ inch thick.

The glass batches could be viewed during the course of melting and a pronounced difference in the gas evolution was noted. Batches $(L + N)$ and $(M + N)$ became quiescent far in advance of batch P; their placid surfaces presented a marked contrast to the bubbling of the latter. At the completion of the tests, glass P contained myriads of fine seeds, while the glasses made from batches $(L + N)$ and $(M + N)$ were not only less seedy, but these seeds were larger and so might be more readily removed.

The conclusion which may be drawn from these preliminary tests is that separate mixing of certain batch constituents may produce homogeneous seed-free glass more rapidly than by the use of a single mixing operation. Two or more separate mixes might be used. The best mixture found in the above tests consisted of batch L + batch N, made in the form of small briquettes, and weighed in proper proportion to produce the desired glass P. Batch L consisted of 577 parts SiO_2 + 384 parts Na_2CO_3; batch N contained 863 SiO_2, 428 $CaCO_3$, 164 Na_2CO_3; batch P was 1440 SiO_2, 428 $CaCO_3$, 548 Na_2CO_3.

Since these tests were made on a laboratory scale, they should be confirmed by factory tests. For the latter, commercial size briquettes should be used and comparative melts made in monkey pots or full-size pots. If such factory-scale tests verify the above laboratory conclusions, the results would indicate that melting tanks might have greater melting capacity by using briquetted batches of differing compositions instead of a single homogeneous mix.

Factory-scale tests would determine also whether the use of different briquettes affected the homogeneity of the glass. It is probable that the capacity of a tank is so great that sufficient time is given for the glass made from different briquettes to become uniform before it reaches the working end.

FRAZIER MAKES PUERTO RICAN SURVEY

J. Earl Frazier of Frazier-Simplex Inc. has just returned from a five weeks' trip to Puerto Rico, which he visited at the request of the Puerto Rican government for the purpose of making a survey of glass manufacturing possibilities. Mr. Frazier informs The Glass Industry that he found conditions most favorable for the establishment of a container plant which, should the government decide to undertake the project, would provide bottles for the great rum making industry of that island.

FTC HEARS FINAL TESTIMONY IN ELASTI-GLASS SUIT

The question whether S. Buchsbaum & Company, manufacturers of synthetic resin articles, may sell the same under the trade name "Elasti-Glass," and represent that the articles are made of "organic glass," is now under consideration by the Federal Trade Commission.

The taking of testimony with respect to the Commission's complaint against the Buchsbaum Company was concluded in Washington during September. Since our latest report of the hearings in this matter, testimony has also been taken in Philadelphia and New York.

The Philadelphia hearing was held to permit the Buchsbaum Company to reopen its case for the purpose of introducing the testimony of Mr. R. E. Hess, Assistant Secretary of the American Society for Testing Materials. Mr. Hess testified concerning the appointment of a subcommittee of Committee E-8 to review and reconcile the definitions of glass which had been adopted by the Glass Committee and by the Textile Committee of the Society. He identified minutes which he had prepared of the first meeting of that sub-committee, the concluding paragraph of which minutes, containing a comment about organic glass, was admitted into evidence.

Hearings were subsequently conducted in New York City, on September 14 and 15, for the purpose of introducing rebuttal evidence on behalf of the Commission. The principal witness was Mr. Charles J. Shaw, Assistant to the President of H. W. Wilson Company, publishers of reference books, indexes and catalogues intended largely for use in libraries. Mr. Shaw's testimony related chiefly to Readers' Guide and Industrial Arts Index, two publications of his company. He asserted that neither of them contains any classification such as "organic glass" or "plastic glass," but that articles dealing with such subjects are indexed under transparent plastic materials.

Other New York witnesses included Kenneth B. Willson, operating manager of the National Better Business Bureau, Inc., who testified concerning the investigation made by his organization and its affiliated bureaus into the propriety of the use of the term "Elasti-Glass" and similar trade names; and other lay witnesses whose testimony related to confusion and public understanding of the terminology involved.

The hearings were concluded with the testimony of Dr. Charles E. Parsons, Secretary of the American Chemical Society, who testified concerning Chemical Abstracts and its indexing methods. This evidence was offered by the Commission to show that Chemical Abstracts did not recognize any such classification as "organic glass," and thereby to refute the contention of the Buchsbaum Company that the term was widely used.

• Labor Director Fred Keightley of the Pittsburgh Plate Glass Company has been chosen by the War Labor Board to serve as a special mediator on labor panels. Representing the employers, he will assist in settling disputes between them and their employees. Mr. Keightley is well qualified for this appointment as he was formerly a commissioner of conciliation of the United States Department of Labor before joining the Pittsburgh Plate Glass Company. He will remain in his present position in the glass company, serving part-time on the Board.

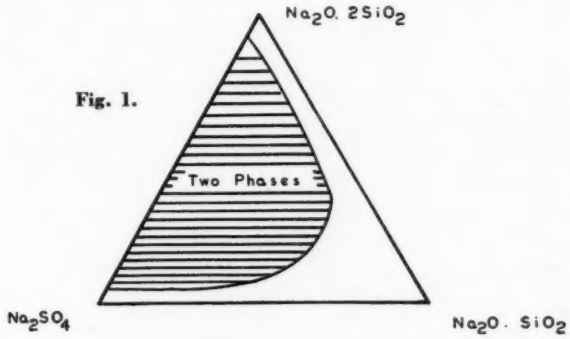
THE ROLE OF SODIUM SULPHATE IN GLASS MANUFACTURE

By WOLDEMAR A. WEYL*

PART II

Sodium sulphate and sodium metasilicate are miscible in all proportions but the addition of only 10% SiO_2 is sufficient to cause the homogeneous melt to separate into two phases. The solubility relationship between sodium sulphate sodium metasilicate, and sodium disilicate can be seen from the schematic picture (Figure 1).

Fig. 1.



This diagram is in agreement with the early observations made by H. A. Seger[16], who was one of the first ceramists to be interested in the relations between silicates and sulphates. He found that a disilicate melt, that means a glass or glaze with the silica: base ratio 2:1 is able to keep approximately 4% sulphate in solution without showing signs of cloudiness. If the silica ratio is increased this solubility decreases rapidly. A trisilicate melt, for instance, dissolves only ½ as much sulphate, namely 2%.

Seger pointed out that during the firing of a glazed piece the glaze changes its composition in a way which might well account for the segregation of sulphates from the homogeneous flux. Silica and alumina go into solution and sulphur dioxide and oxygen will be liberated at the glass-body interface where they cause a characteristic defect called boiling.

This sequence of reactions taking place in the batch is only slightly modified when other constituents are present. G. Marchal[6] made several studies on the reactions of silica and alumina with the sulphates of calcium, magnesium, and barium, and he found that the reactions leading to silicates and aluminates are considerably lowered when a proper amount of carbon is supplied. The reducing agent must not necessarily be carbon but can be hydrogen gas or carbon monoxide as well. B. Bogitch[17] studied how the decomposition of sodium sulphate by silica is affected by different gas mixtures and H. O. Hofman and W. Mostowitsch[18] made similar investigations on the influence of CO on the dissociation of $CaSO_4$.

The fundamental importance of these reactions for melting plate and window glass stimulated quite a few research projects in glass plants. H. Salmang and A. Merten[19], for instance, followed the changes taking place in a glass pot containing about 2000 pounds of a plate glass batch each. The batch composition was:

300 parts sand
102 parts limestone
100 parts sodium sulphate
13 parts soda ash
5 parts coke

Samples were taken from the melting glass as soon as the last charge had melted down and the gall had not yet completely disappeared. During the removal of the glass and shortly afterwards the glass was still yellow from the presence of sulphides and polysulphides. Even 2½ hours after the last charge, hydrogen sulphide was still noticeable when a sample was crushed in a mortar. The last traces of sulphides were driven out by a blocking operation using a piece of wet wood. The gradual decrease of the SO_3 content can be seen from Table I.

TABLE I

Time Melting Schedule		Temperature °C	SO_3 Content %	Remarks
P. M. 4:50	80 min.	1455	4.49	yellow containing Sulphates
5:15	105	1450	0.81	
5:30	120	1415	0.77	
6:05	155	1420	.68	5:45 begins fining period
6:35	185	1440	.61	
6:50	200	1455	.72	
7:35	245	1455	.58	
7:55	265	1458	.56	
8:35	305	1420	.64	
8:55	325	1430	.53	
9:15	345	1420	.53	
9:45	375	1420	.53	10:00 end of fining period
10:15	425	1400	.46	
10:45	455	1400	.53	
11:45	515	1380	.61	

The amount of carbon required for the decomposition of the sodium sulphate varies considerably depending upon many factors. 5 to 7% of the weight of the salt-cake is the rule. Theoretically, using the oxidation to carbon dioxide as a basis, 4.22% would be sufficient but some of the coal burns without reducing the sulphate. In plate glass production it has been found advisable to have a small amount of sodium sulphate in excess, so that glass gall forms on top of the melt. The glass gall can be removed by throwing coal or an intimate mixture of coal and finely ground sand on top of it.

There are some cases, however, where the complete removal of the glass gall seems to be undesirable. The suggestion of L. Bock[2] to use the glass gall as a protection against reducing influence does not need further explanation. More difficult to understand is the technique used

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in certain glass plants in Belgium where large carboys are blown. R. Dralle[20] reports that it was customary in a Belgium glass plant specializing in large carboys, to adjust the batch so that a heavy layer of glass gall is covering the pot after completion of the melt. Asked about the reason for this procedure, the workers claimed that deviations from this method yielded a lower quality glass which is more brittle and when subject to the pressure test shows a considerably lower strength.

In many plants alkali is introduced in both forms, sodium carbonate and sodium sulphate. H. Jebsen-Marwedel[21] made an extensive study on the reactions in such a mixed glass batch and paid particular attention to the gases liberated. This work gives us the first data of the temperature distribution in a batch pile. The batch is a good thermal insulator and it takes a long time to heat up the interior part. This indicates that the reactions which we have just discussed take place relatively slowly. It has been the common belief that the sequence of reactions in a melting batch is rather immaterial, as there is no time to distinguish between the different phases.

How Much Sulphate Remains in the Glass?

Since the early observations of Pelouze that a part of the sulphate can remain in a glass, the glass technologists have been interested in finding out more about this constitutent, especially, how it affects the properties. Research carried out by Seger on glazes and Gelstharp, Salmang, Jebsen-Marwedel, and Becker on glasses reveal that an equilibrium is established between the sulphate and the silicate in the melt at the one side and the sulphur dioxide and oxygen content of the furnace atmosphere on the other. From the equation:

$$SiO_2 + Na_2SO_4 = Na_2SiO_3 + SO_2 + \tfrac{1}{2} O_2$$

we see that the equilibrium concentration of the sulphate must decrease with increasing silica content of the glass and decreasing SO_2 concentration in the atmosphere. Lack of oxygen, addition of reducing agents, or the presence of carbon monoxide in the furnace, too, will tend to lower the sulphate concentration.

The equilibrium can be reached from both sides. In our present discussion, the dissociation of the sulphate is our chief concern but in a later chapter we will discuss also the reverse reaction. Also a sulphate free batch might yield a sulphate containing glass or in extreme cases even develop glass gall when the furnace atmosphere is oxidizing and SO_2 is present.

The influence of the acidity or the silica content of a glass on its sulphate content has been described by Seger. Obviously this relationship is more interesting to the ceramist who works with glazes of widely variable composition than to the glass melter whose product does not change as much in its silica content.

H. Jebsen-Marwedel and A. Becker[22] made an exhaustive study of the sulphate content of a glass as affected by temperature, time, and furnace atmosphere. They worked with glasses of the following composition range:

SiO_2	72.5 to 73.0%
Al_2O_3	0.5%
CaO	13.2 — 13.8%
Na_2O	13.5 — 14.0%

In each glass, 2% alkali were introduced in the form of sodium sulphate, the rest 11.5 — 12%, as carbonate. No carbon was added to the batch.

When such a glass was melted in a platinum crucible at 1350°C for a period of 4 hours, it contained approximately 0.8% SO_3. In air, that means under oxidizing conditions, all values were fairly well reproducable, but when a reducing atmosphere was used the results scattered considerably. In the presence of carbon monoxide the decomposition of the sulphate was chiefly determined by the speed of diffusion of this gas into the melt. This reaction took place only from the surface and, consequently, was subject to the currents set up in the melting crucible. Despite this inaccuracy, the results show clearly the trend how the different factors influence the SO_3 content of a glass. For a quantitative interpretation, of these results we have to consider that the volume to surface ratio of the glass comes in as a modifying factor. Furthermore, the heat distribution and the resulting currents must be of considerable influence. Each glass melting unit, therefore, has to be treated as an individual.

(a) The Influence of Temperature and Time on the Sulphate Content under Oxidizing Conditions

When the melting of the glass is continued at 1350°C over a period of 24 hours in an atmosphere containing 5 to 7% oxygen, only a slight decrease of the SO_3 content is noticeable. At higher temperature the SO_3 content falls off more rapidly, Figure 2.

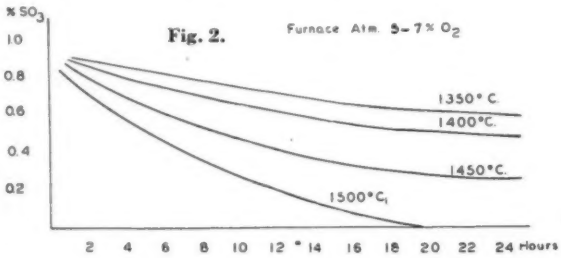

Fig. 2.

Over a period of hours the SO_3 content at:

1350°C	changes from 0.8% to 0.6%
1400°C	to 0.5%
1450°C	to 0.2%
1500°C	to 0.0%

(b) The Influence of Temperature and Time on the Sulphate Content under Reducing Conditions

The same glass melted in an atmosphere containing 5 to 7% carbon monoxide loses its SO_3 more rapidly. Already at 1200°C a slight decrease becomes noticeable and at 1350°C the decomposition of the sulphate under reducing conditions is as fast as at 1500°C under oxidizing conditions. The average values of the SO_3 content as affected by time and temperature are plotted in Figure 3.

Not all the sulphur has escaped into the atmosphere but a part remains fixed in the glass in the form of sulphides. That can be seen from the brown color which penetrates with the carbon monoxide from the surface of the melt into the deeper regions.

Effect of Sulphate on Melting and Fining

In the previous chapter we came to the conclusion that major amounts of alkali in the form of the sulphate can

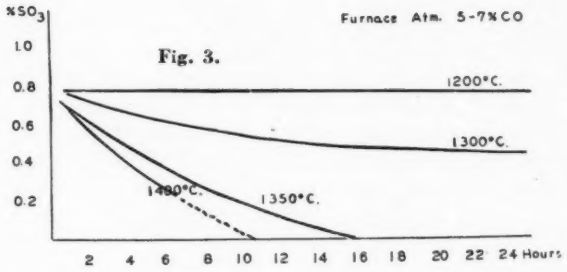

Fig. 3.

be introduced into the glass only when sufficient carbon is added to the batch to make the sulphate "soda-like." If salt cake is introduced with insufficient amounts of carbon then it does not react like soda-ash but maintains its own characteristic features. The behavior of free sodium sulphate can be traced back to its property to be stable in a glass melt up to high temperatures. Partly the sodium sulphate is dissolved in the melt, partly it segregates and forms its own liquid phase, thus providing a potential source of reactive alkali and oxygen. The fact that it makes the alkali and oxygen available during a later stage makes this compound an excellent fining and oxidizing agent as well as a remedy against the formation of scum.

(a) Scum, Its Formation and Prevention

One of the first observations made by the glass melter who switched over to the sulphate free Solvay soda was the formation of scum on top of the melt. So long as glass was melted in small units this surface scum was not taken very serious for it could be easily scraped off before working out the glass. When large melting units and continuous tanks came into use scum formation became a serious handicap and the glass technologists made efforts to avoid it. Addition of a certain amount of sulphate without coal or an insufficient amount of carbon to reduce all of the sulphate was found to be the best remedy.

F. Gelstharp and J. C. Parkinson[11] studied the practical fields of glass formation in the ternary system, sand, soda ash, limestone, and came to the conclusion that scum formation is one of the limiting factors in the manufacture of clear glasses. The field of possible glasses, could be considerably extended when a part of the alkali was introduced in the form of sulphate. They assumed that sulphate has the property to bring certain polysilicates in solution which otherwise would not react with the sodium silicate melt. This explanation was based on the observation, that the scum which formed on top of the glass had a relatively high silica content and that it was not readily attacked by the fused part of the batch. Today we can be more specific and explain the phenomenon as follows:

Sand consisting of single round quartz crystals reacts with soda ash in two different ways. The liquid sodium carbonate or its eutectic with sodium silicate attacks the surface of the grain bringing about gradual solution. Besides this desirable reaction the quartz undergoes a change from the low into the high temperature modification which causes the crystals to crack due to the sudden volume change accompanying this transformation. The fluid polyeutectic melt now penetrates into the fine cracks and catalyzes the inversion of high quartz into cristobalite. This process brings about a considerable volume change and a decrease in density from 2.6 to 2.3 so that the cristobalite grains are driven to the surface of the melt. Especially when the melt is still fluid the conversion of quartz into cristobalite brings about a rapid separation between silica and alkaline melt which finally leads to a scum. On the surface the grains stick together, cemented by a glass which acts as a bond. If, however, sodium sulphate separates out at the same time it too rises to the surface accompanying the silica grains. Now the picture is completely changed. The sodium sulphate under the influence of the reducing furnace gases reacts with the silica and caused the scum to go into solution. The amount of sodium sulphate should be sufficient to accomplish this task. Excessive amounts of sulphate represent a real danger, for the alkali liberated at the high temperature presents itself in a uncombined and reactive form which might seriously injure the refractory.

(b) Sodium Sulphate as a Fining Agent

When the fining effect of sodium sulphate was first observed the mechanism of this phenomenon was not yet clearly understood. From the early observations of Girardin and Schott it was known that small amounts of chlorides present in the glass melt enter the sodium sulphate phase and are, therefore, withdrawn from the glass melt. G. Keppeler assumed a similar process to take place with the residual carbonates. Sodium sulphate was supposed to sweep out undecomposed carbonates, thus eliminating the formation of new bubbles and seeds in a later stage of the melt. Furthermore, it has been suggested that the part of sodium sulphate which is soluble in the silicate melt influence its surface tension in a way favorable to the elimination of gas bubbles. All these statements, however, were rather vague and lacked experimental support.

E. Zschimmer, E. Zimpelmann, and L. Riedel[23] made the first extensive study of the fining action of sodium sulphate in soda-lime-silica glasses with and without alumina. They offered a physical chemical explanation which was based on the progressing dissociation of carbonates and sulphates with increasing temperature. Their research lead to a type of heat treatment known as "Zschimmer's Temperature Shock."

A precise and generally applicable picture of the fining action of sodium sulphate as well as other fining agents was derived by G. Gehlhoff, H. Kalsing, and M. Thomas[24]. They came to the conclusion that the essential features of a good fining agent are to keep oxygen up to high temperatures, also that it is available during the fining interval, and that the decomposition product should be able to react with the gas liberated when the melt is allowed to cool down to the working temperature. Sodium sulphate fulfills both conditions. In the fining range it decomposes according to the equation

$$Na_2SO_4 \longrightarrow Na_2O + \tfrac{1}{2}\,O_2 + SO_2$$

liberating oxygen. The mixture of sulphur dioxide and oxygen bubbles through the glass withdrawing carbon dioxide, water, and other gases from the melt, thus exerting a fining action. Small seeds containing SO_2 and O_2 in the proper ratio which did not find a chance to reach the surface are readily absorbed by the glass when the

melt is cooled down from the fining to the working temperature.

G. Gehlhoff and his co-workers found that sodium sulphate has a distinct optimum in its fining efficiency when introduced in amounts between 0.4 and 0.5%. These values have been derived from experimental melts in the laboratory and confirmed by large scale melts in the glass plant. In order to obtain figures which would at least approximately describe the efficiency of a fining agent the seeds per unit volume were counted. Figure 4 illustrates the effect which increasing amounts of sodium sulphate have on the number of seeds per ccm. of the glass. Small amounts seem disadvantageous. 0.4 to 0.5% has a maximum effect, and when the amount of sodium sulphate exceeds this percentage the number of seeds per unit volume increases again. The Curve I, represents the data obtained from laboratory melts held for two hours at 1400°C, and curve II refers to the large scale experiments in which samples were taken from the middle of the pot 12 hours after the last charge, at an approximate temperature of 1400°C.

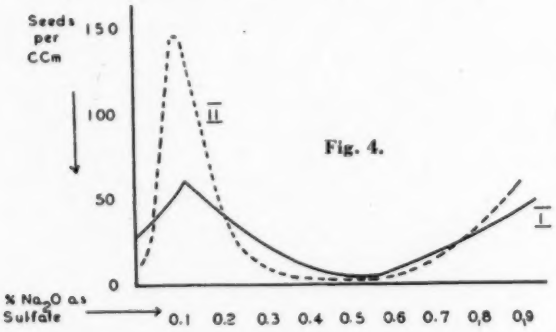

Fig. 4.

Based on this experimental evidence Gelhoff and his collaborators recommend introducing about 1/20 of the alkali in the form of sodium sulphate.

(e) The Color of Glass as Affected by Sodium Sulphate

The very fact that sodium sulphate meets the requirements of a good fining agent already includes that it must exert a beneficial influence on the decolorizing of glass. Indeed the mixture of sulphur dioxide and oxygen which is liberated during the fining range creates oxidizing conditions and shifts the iron oxide equilibrium to the side of Fe_2O_3. This simple reaction can be applied only to small additions of saltcake such as used for fining purposes. When larger amounts of sulphate are introduced and the carbon has to be added to the glass batch, the effect of saltcake is much more complicated. From the chapter dealing with the chemical reactions taking place in the glass batch containing both sodium sulphate and carbon we have learned that sodium sulphide is formed as an intermediate product. In pure soda-lime glass, sulphides or sulphur ions are not very stable. They are easily oxidized to polysulphides then to sulphur dioxide and consequently burn out when slightly oxidizing melting conditions are maintained.

In a recent paper[25] on the role of sulphur in a glass we have discussed this behavior on a structural basis. The presence of S^{2-} in the glass means that sulphur ions replace part of the oxygens so that the strong Si—O—Na bond is replaced by the much weaker Si—S—Na linkage. We learned that heavy metal ions, especially zinc ions in the glass exert a stabilizing action on the sulphide. Some of the zinc ions replace Si^{4+} which gives the S^{2-} a possibility to take positions neighboring zinc ions rather than silicon ions. That leads to the stronger bond, Zn—S—Na. An action similar to the zinc is observed by the trivalent iron. A part of the ions of the trivalent iron Fe^{3+} assume positions comparable to those of the Si^{4+}, forming FeO_4 groups. When one or more of the oxygens are replaced by sulphur ions the brown color of the FeO_4 group becomes still deeper. Such an iron-sulphur complex is so stable to oxidation that even in the presence of sulphate a certain amount of iron sulphide can be formed in the glass. During the melting of a batch containing saltcake and carbon some of the sulphide is stabilized by the iron and it takes a long time to remove this color by oxidation. Jebsen-Marwedel found that carbon amber glasses—which have iron sulphide or the complex Fe^{3+}—S—Na as a chromophor group—contained still up to 0.3% free sulphate.

The brown discoloring can be avoided only by a proper carbon: sulphate ratio, careful mixing, and the use of blocking agents during a later stage of the melt

When manganese was still the only decolorizer for glass the introduction of saltcake offered a serious problem. Manganese was reduced to its divalent state by the presence of carbon and the sodium sulphate has too low an oxidation potential to change it back into its trivalent state. The divalent manganese was ineffective for only the trivalent manganese gives rise to pink color which is essential for compensating green iron color.

One way out of this difficulty has been described by F. Guhrauer[26] (1875) who melted his glass in two steps. First, he made a frit from the batch containing saltcake and carbon and then, he remelted the frit and only now he added the manganese to the carbon-free glass. This method was not so unusual at this time for many types of high grade glass, especially colored glasses were manufactured this way.

Another method which had been considered was not to sell saltcake but sodium silicate to the glass industry. R. Wagner[27] for instance, pointed out the tremendous loss of sulphur in the English plate glass industry resulting from the use of saltcake as a batch ingredient. The sulphur dioxide liberated from the melt cannot be recovered economically in the glass plant. He suggested that alkali plants take over this process, convert the sulphate into silicate, regaining the sulphur from the SO_2 and offering the fritted silicate to the glass industry as a batch ingredient.

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GLASS PRECISION GAGES . . .

a war baby destined for civilian use

Although a wartime development to conserve critical tool steel, glass gages are expected to become a permanent fixture in industrial post-war manufacturing.

By COL. H. B. HAMBLETON
Chief, Gage Section, Office, Chief of Ordnance

Gages for use in the manufacture of munitions were, no doubt, the last thing the glass industry dreamed of making from glass. Tough tool steel has always been the materiel from which these exacting items have been fashioned. The unpredictable however has happened, glass gages are efficiently taking over in the field of steel gages. This change was made through research conducted by the Ordnance Department of the U. S. Army. It was made necessary by the fact that tool steel was critical and badly headed elsewhere in the war effort. While still more or less in the experimental stage, six months use at the Frankford Arsenal and elsewhere have proved glass gages to be the equal of, if not superior to steel gages. In fact, so efficient are glass gages that they are fully expected to become a permanent fixture in the industrial world after the war.

Types of glass gages replacing steel gages.

For those glass makers unfamiliar with gages in general, let me say that the plain gages adaptable to this substitution in material, can be roughly described as small blocks, rods and rings, machined to very exacting measurements. They are used by inspectors to check the accuracy of the items or parts made in various factories. They constitute one of the foundation blocks of mass production, which in turn is based on the interchangeability of parts. Without them production would cease; without great accuracy in gages, whether of steel or glass, the fighting weapons of our soldiers would inevitably fail them in battle.

First off, glass gages, with their frangibility characteristic, would seem to be an anomaly, especially in view of the fact that until now, gages have been made from the toughest of steels. This anomaly dissolves when one reviews some of the characteristics inherent in glass.

In the first place, frangibility is not the liability one might at first expect, in fact, it is an asset, for it teaches the inspectors to have respect for a very nice tool. Furthermore, a dropped gage either breaks beyond repair and thus automatically retires itself, or it is undamaged and its usefulness unimpaired. On the other hand, a dropped steel gage is always under suspicion until checked in the laboratory, for it may be bent or sprung just enough to go undetected by the inspector and thus pass poor work.

The Ordnance Department will accept gages or gage blanks made from either lime glass or boro-silicate (Pyrex) glass or a light flint glass. However, it does not hold rigidly to the above types but will accept gages of glass of different composition if full and sufficient proof is provided that such proposed gages are equal in all respects to the gages covered by its specifications. Maximum hardness, maximum abrasive resistance and dimensional stability are requisite. In this connection, we might state that the boro-silicate formulas are among the hardest and most abrasive resistant and the thermal expansion is only about a third or a quarter of the thermal expansion of most metals and this includes the carbon steels.

Increased dimensional stability is also obtained through another physical property of glass — its lower thermal conductivity as compared with steel. Due to the exceptionally small tolerances required on much of our munitions production, even the heat from the inspector's finger will occasionally expand a steel gage to a point where considerable trouble is caused thereby. The thermal conductivity of glass is so low, that no difficulty is experienced from this factor.

Another physical property inherent with glass is a coefficient of expansion that is low, but which can be made to vary by changing the composition of the glass. Through this control, glass for gages can be made up with almost any desired coefficient of expansion, which is a

(*Continued on page* 78)

Checking the diameter of a cartridge case with a glass gage.

WPB LIMITS INVENTORY, PRODUCTION IN NEW ORDERS

While the new Consumers' Goods Inventory Limitation Order L-219 is primarily concerned with retailers and wholesalers it does affect certain manufacturers' inventories. When a manufacturer maintains a branch office stock inventory of consumers' glassware having a cost value of $50,000 or more at the end of any quarter of his federal income tax year and a net sales in that branch of $200,000 or more during the 12 months preceding the end of the same quarter of his federal income tax year, then he comes under its provisions.

This order also provides for the punishment by fine or imprisonment of any manufacturer found guilty of violating any of its provisions and he may be prohibited from securing or using materials under priority control. A violation of this order is understood to mean the increasing of controlled mercantile inventories by the manufacturer beyond the limits established by the order.

According to a previous order issued by the War Production Board, retailers and wholesalers will not be held liable for any contract for goods which they cannot accept because of the inventory limitation. Faced with the possibility of being left with goods from cancelled orders, it may be necessary for leading manufacturers to consider a means of investigating the inventory status of their large customers before accepting sizeable contracts for a future date.

There are rumors of further far-reaching limitation orders to be evolved in the near future which would affect retailers, wholesalers and manufacturers of glassware. Not as yet issued but being discussed in W.P.B. circles is a Master Limitation Order which would cover all products. Only those items mentioned in the O[illegible]er would be allowed to be manufactured and all other goods would automatically disappear from the market. As soon as existing stocks become exhausted, the listed products would be limited to a certain percentage of production and critical materials involved would also be restricted.

In order to have their products listed in the Order, manufacturers would probably have to prove their indispensability to the war effort and show that they are doing all they can to conform to the requests of the War Production Board in transportation, substitution, and the reduction of waste in production to a minimum.

GAS LIMITED FOR INDUSTRY

According to two new limitation orders, Order L-31 and L-174, affecting all industrial plants, glass manufacturers face the danger of having their gas supplies cut off if they do not try to convert their equipment to use less fuel, and if they are not providing their stand-by equipment with fuel to operate. This pertains to plants using either natural or manufactured gas.

A serious natural gas shortage has already been felt in the Indiana-Illinois territory during the past month, causing production losses to a number of glass factories. Several factories were forced to shut down entirely; those in Marion, Muncie, Streator, and Sterling in particular were affected. The abnormal demand for home-heating purposes plus the added needs of a great number of war industries in the locality are thought to have been contributing factors to the shortage.

REVISED O. D. T. ORDER INCLUDES GLASS PRODUCTS AND MATERIALS

Glassware, glass containers and chemicals were among the 18 new commodities added to the list of goods for which special loading requirements have been prescribed for carload shipments by rail by the Office of Defense Transportation, effective January 4, 1943. Under the general order railroads are prohibited from accepting carload shipments, other than of excepted commodities, which do not fill a car either to its marked weight capacity or to its visible capacity.

The following excerpts from the revised Special Direction ODT 18 pertain to the glass industry:

Under Containers:

Glass: Bottles, jars and packing glasses, (other than those manufactured from opal glass), in barrels, boxes or crates, shall be loaded to an elevation not less than 7 feet from the floor of the car, covering the entire floor space of the car;

(a) Jars manufactured from opal glass, in barrels, boxes or crates, shall be loaded to a weight not less than 60,000 pounds;

(b) Bottles and jars, loose in the car, shall be loaded to an elevation not less than 5 feet from the floor of the car, covering the entire floor space of the car.

Under Glassware; (Cut and other than cut, n.o.i.b.n., including tumblers, other than cut, n.o.i.b.n., in straight or mixed carloads):

(a) When loaded in cars 50 feet or more in length shall be loaded to a weight not less than 45,000 pounds;

(b) When loaded in cars less than 50 feet in length shall be loaded to a weight not less than 36,000 pounds;

Glass:

(a) (flat, plate, window, and laminated) shall be loaded to a weight not less than 70,000 pounds.

(b) (wrought rolled, wired, and polished, wired) shall be loaded to a weight not less than 60,000 pounds.

Under Chemicals:

Potassium Carbonate:

(a) In barrels of approximately 400 pounds gross weight each, shall be loaded to a weight not less than 70,000 pounds;

(b) In barrels of approximately 450 pounds gross weight each, shall be loaded to a weight not less than 80,000 pounds;

(c) In drums, barrels, or casks, exceeding 500 pounds gross weight each, shall be loaded each container placed on end, in one tier covering the entire floor space of the car.

Chemicals (not otherwise named herein):

(a) In boxed carboys, shall be loaded not less than three tiers in height, with 4 carboys across the width of the car floor the entire length of the car, 3 carboys on the second tier across the width of the car and along its entire length, and 2 carboys on the third tier across the width of the car and along its entire length, subject to I.C.C. regulations on specific commodities;

(b) In drums, barrels or casks, 500 pounds or more in weight each, shall be loaded, each package placed on end, in one tier covering the entire floor space of the car.

• Latest reports from Germany tell of a shortage of window glass which hampers the building of new houses and the heating problem in the bombed cities.

Research Digest

Practical Interpretations of Glass Technology

The Behavior of Tuckstones in a Glass Tank Furnace

Of direct interest to furnace men is the recent paper by Partridge (Journal Society Glass Technology, August, 1942) on the subject of tuckstone deterioration, as it shows how well theory and practice can work together towards the solution of refractory problems.

The wearing away and the formation of a spongy corundum layer of certain aluminous tuckstones (40 per cent alumina) used in a furnace melting a soda-lime-silica glass at normal temperatures was shown to be due to a peritectic reaction, which, in this particular case, resulted in the precipitation of corundum crystals and the formation of a siliceous liquid. The siliceous liquid, being sufficiently fluid at the operating temperature, flowed down upon the faces of the tank block causing not only grooving of the tank blocks and contamination of the glass with aluminous cord-forming material but due to the resulting shrinkage of the tuckstones exposed the top surfaces of the tank blocks.

As the fluidity of the glassy bond therefore seemed to control to a great extent the life of the tuckstones, a series of experiments involving both the measurement of "creep" strength and corrosion resistance was made on a group of various refractory materials. These laboratory tests indicated that silica should be a more satisfactory tuckstone material than any of the other materials tested. Accordingly, several test panels of silica tuckstones were installed in two tank furnaces. Actual usage confirmed the laboratory results. The silica, after service, showed only a small reduction in size and with the exception of some pitting being observed, the degree of corrosion was not excessive. It may be remarked that neither sillimanite nor fused cast high alumina materials were included in the tests.

Cords, Surface Condition, and the Quality of Glassware

Holland, Preston and Turner in the August 1942 issue of the Journal of the Society of Glass Technology have presented an excellent paper on the subject of cord and surface defects in which the better known methods of demonstrating and measuring such defects are reviewed and new methods of measuring both cord and surface defects are described.

In the study of cord, three methods were used: 1—the shadow method, using polished discs of glass in ordinary light; 2—the polariscope method, in which the glass discs are examined for their degree of cord strain by the means of polarized light; and 3—a photo-optical method which is a modification of the well known method used for the detection of cord in optical glass, but modified in such a manner that through the use of a photo-electric cell to measure the light not scattered by the cord present in the glass sample, a numerical value expressing the amount of cord may be obtained.

As a "glass as glass" method this photo-optical technique seems to give quite excellent results as shown by the data obtained on samples of intentionally cordy glass taken at different melting times. In the case of the subject of the effect of cord on container strength (this is the phase of the subject that the American technologists seem to be most interested in) this method in its present form is not entirely suitable as it ignores the cord strain that is present. A further modification, such as the use of the photo-electric cell along with the polariscope ring section technique may prove to be more useful for this special case.

Surface markings were investigated by the use of shadow photographs and by microscopic examination using oblique illumination and a magnification of 50x. This latter method gave excellent results in a study of the deterioration of the surface condition of mold blown ware with increasing age of the mold.

The original paper should be consulted by those interested as it contains numerous photographs illustrating various cord and surface conditions.

The centrifuge method of Turnbull and Ghering was given a preliminary trial but due to the inability of obtaining one of the essential flotation liquids no extended tests were carried out with this method of estimating cord.

Possibilities of Strontia in Ceramics

Strontium, once considered quite rare, due to war demands has become plentiful by virtue of the development of new resources. At present a limited amount is available for ceramic use but after the war period this limitation will be over. Already an extensive research program is under way on a study of its uses in glazes. According to Kreidl (Foote-Prints,* 1941, No. 2) strontia may be of some use in glassmaking. Partial replacement of calcia and barium by strontia in glasses results in various improvements. For example: in barium crown glasses the use of strontium assists in preventing crystallization. Viscosity characteristics, electrical properties and chemical durability are also influenced by strontium.

Kreidl's paper is an excellent summary of the history, theory and use of strontia in glass and other ceramics and should be read by those interested in studying the possibilities of strontia in glasses.

Calculation of Density and Optical Constants

In various papers, Huggins has assembled the published data on density and optical constants of glasses, and reduced them to a series of equations, the use of which allows the fairly accurate calculation of density and optical values from the chemical composition of the glass.

Originally these equations were in such a form that it was difficult to work with them, especially in the case of routine computations. Huggins and Sun (Journal American Ceramic Society, January, 1943) now have con-

(*Continued on page* 79)

*Foote-Prints is a publication of the Foote Mineral Co., Philadelphia, Pa.

MICHIGAN ALKALI AND J. B. FORD CO. FORM NEW CORPORATION

The Michigan Alkali Company and the J. B. Ford Company have announced their consolidation as the Wyandotte Chemicals Corporation on January 1, 1943. Mr. E. M. Ford, formerly vice-president and treasurer of Michigan Alkali Company, will be the president of the new corporation, the position which was to have been held by his father, E. L. Ford, who died suddenly on December 20.

I. H. TAYLOR
Vice President
in charge of sales

In announcing the consolidation Mr. Ford explained that the personnel of the two companies will remain the same and that there will be no change in ownership, the move being made entirely for more efficient operation and distribution. F. S. Ford and W. F. Torrey are vice presidents of the new corporation; Ford Ballantyne is secretary and treasurer. S. T. Orr will become vice president in charge of manufacturing; I. H. Taylor, vice president in charge of sales; G. W. Schwarz, controller; D. G. Robinson, vice president in charge of sales J. B. Ford Division; and Bert Cremers, vice president in charge of sales, Michigan Alkali Division.

BERT CREMERS
Vice President
in charge of sales
Michigan Alkali Division

The Michigan Alkali Company, established 52 years ago, is one of the largest producers and distributors of chemicals, including soda ash, caustic soda, chlorine, calcium carbonate, and bicarbonate of soda. Its sales division will now be responsible for sales in the soap, paper, chemicals, flour mill, rayon, oil refinery, synthetic rubber, steel, aluminum, coal mine, and public highway industries.

The J. B. Ford Company manufactures specialized cleaning materials and is now engaged in war production.

• The Optical Society of America has announced that their mid-winter meeting will be held at the Hotel Pennsylvania, New York, N. Y., on March 5 and 6, 1943. The Inter-Society Color Council will meet on March 4.

A.C.S. TO HOLD ANNUAL MEETING

The week of April 18, 1943, has been definitely decided upon as the time for the 45th Annual Meeting of the American Ceramic Society at the Hotel William Penn in Pittsburgh. The Glass Division shows early indications of having a program on war problems, and as usual a list of papers to be read at the meeting and the full list of events will be published in the March and April issues of The Glass Industry.

DR. TAYLOR ELECTED TO FELLOWSHIP IN BRITISH SOCIETY

Dr. Nelson W. Taylor, for ten years head of the Ceramics Department of Pennsylvania State College, has been elected to a Fellowship in the Society of Glass Technology, Sheffield, England.

Dr. Taylor has developed the Department of Ceramics at Pennsylvania State College until it is now recognized as one of the more outstanding college departments in the field of ceramics and glass technology.

He has held the Guggenheim Memorial Foundation Fellowship, under which he studied in Berlin and Gottingen, Germany. A graduate of the University of Saskatchewan, he received his Ph.D. degree from the University of California. During World War I he served in the Royal Air Force as a 2nd Lieutenant.

Dr. Taylor, a Fellow of the American Ceramic Society, has been the Chairman of the Glass Division, and in 1936 was the American Delegate to the International Congress of Glass Technology in London and Sheffield. He is also a member of the American Chemical Society and chairman of its Central Pennsylvania Section.

As author and co-author, Dr. Taylor has published over fifteen technical papers since 1935, and has acted as technical consultant to several companies on physico-chemical problems.

• Thomas A. Collins, former manager of the Western factories of Owens-Illinois Glass Company, has been elected vice-president of the Libbey Glass Company, according to an announcement recently made by John H. Wright, president and general manager.

SCIENTIFIC DIRECTOR NAMED FOR FIBERGLAS LABORATORIES

Dr. Albert W. Davison of Rensselaer Polytechnic Institute has been chosen the new scientific director of the Owens-Corning Fiberglas Corporation's research laboratories at Newark, Ohio.

Dr. Davison has headed the industrial engineering curriculum at Rensselaer since 1935 and is a co-author of the Laboratory Manual of Physical Chemistry, published by John Wiley and Sons, Inc. He received his Master of Science degree from Ohio State University and his Ph.D. from Cornell. Leaving his position at the University of Cincinnati during the first World War, he served as first lieutenant of Ordnance and as a captain in the Chemical Warfare Service.

The Owens-Corning Fiberglas laboratories are at the present time engaged almost 100 per cent in the war program developing glass fiber materials to meet vital needs.

INVENTIONS AND INVENTORS

A Summary of United States Patents of Interest to the Glass Industry Issued During December

Furnaces:

Walter W. Oakley of Corning Glass Works suggests in patent 2,304,196 illustrated in Fig. 1, that refractory flux blocks be made in such form that their centers of gravity will lie outside their base. Thus they will be supported by the underlying blocks and according to the patent will tend to maintain tight joints due to the action of gravity.

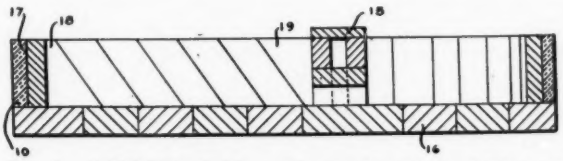


Fig. 1. 2,304,196: Oakley. To provide joints which tend to stay closed, the flux blocks are so shaped as to be "off-balance" and to press down on each other.

Feeding, Forming and Shaping

Pittsburgh Plate Glass Co. received two foam-glass patents: 2,306,330, granted to Philip H. Dewey of Pittsburgh and 2,306,310, granted to Elmer H. Haux of Detroit. The Dewey process consists of bubbling carbon dioxide through molten glass containing sulphates until these two agents react. The reaction is evidenced by the liberation of many small bubbles which are entrapped by chilling the viscous glass. In the latest Haux method the gas forming material, mixed with powdered glass, is placed in a mold in which a cover plate can move upward to a predetermined position. The charged mold is heated until the mixture sinters and expands to be flattened against the cover plate.

The series of illustrations comprising Fig. 2 shows the stepwise formation of a glass article open at both ends, by one of the methods disclosed in patent 2,306,132 issued to Paul R. and Walter O. Luertzing. A charge is drawn by suction into a mold of annular form; the blank is then pressed from each end to make it thicker in the middle; intermediate portions of the mold walls are then removed, the blank is drawn out longitudinally, and correspondingly longer mold walls are brought into place; then the blank is subjected to internal pressure which expands it into contact with the mold walls to give final shape to the glass article.

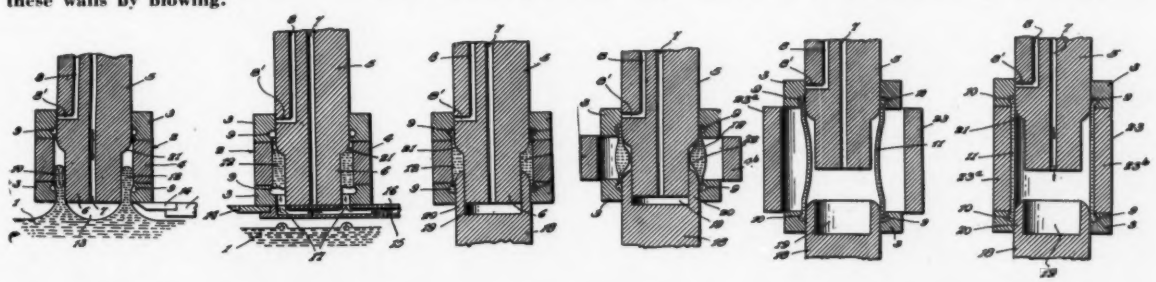
To replace the manual weighing of products from a continuous forming machine so that the operator may control the charge accordingly, Wm. L. McNamara of Connellsville, Pa. provides an automatic weight regulator in patent 2,306,789 assigned to the Capstan Glass Co. The mechanism provides for periodically weighing the product of a given mold (to prevent errors due to differences between molds); if the scale indicates that the charges depart more than a predetermined amount from the desired weight, electrical contacts are closed, there being a separate contact for overweight and another for underweight. The closing of the contacts operates relays which start and operate a motor for changing the feeder adjustment.

Owens-Illinois Glass Co. was assignee of patents 2,304,727 issued to Joseph P. Benoit of Alton, Ill., and 2,304,736 issued to Harry M. Louden and Cecil W. McCreery of Muncie, Ind. The Benoit patent comprises certain improvements in the means of controlling the application of suction to molds. In the Owens type of machine the movements of the plungers which pick up the charge are controlled by stationary operating cams. In the standard practice of adjusting these cams there is also a change in the relation between the lowering of the mold and the opening of the vacuum valve for the suction gathering operation. To maintain a constant relationship between these operations, Benoit operates the vacuum valve by an air piston motor controlled by means connected with the dip cam. The Louden-McCreery patent involves a mold locking device for the two halves of a glass block mold, which locks them positively before the pressing station is reached and holds them together until the take-out station is reached.

In patent 2,305,739 Orie Shackleford of Fairmont, W. Va., describes the feeding device shown in Fig. 3. One novel feature is the provision of a chain-driven refractory rotor 7 which governs the amount of glass allowed to flow into the well in which the plunger 16 operates. The centrifugal force incident to the spinning of this rotor tends to retard the feeding of the glass, and by altering its speed and is depth of immersion the flow can be entirely interrupted or otherwise controlled. A heating element within the plunger allows it to be heated.

Lens forming processes are described in patents 2,304,-

Fig. 2. 2,306,132: Luertzing. In these six steps of forming open-ended ware, (1) the charge is drawn up by suction, (2) severed, and forced into an annular space by air, (3) pressed to enlarge the center, (4 and 5) stretched out from top and bottom while the mold walls are replaced by longer ones, and (6) given a final shaping against these walls by blowing.



217 to Edgar D. Tillyer of Southbridge, Mass. (American Optical Co.), 2,304,663 and 2,304,664 to Chas. V. Smith of Dayton, Ohio. The last two patents are assigned to the Univis Lens Co. and concern resinous plastic materials.

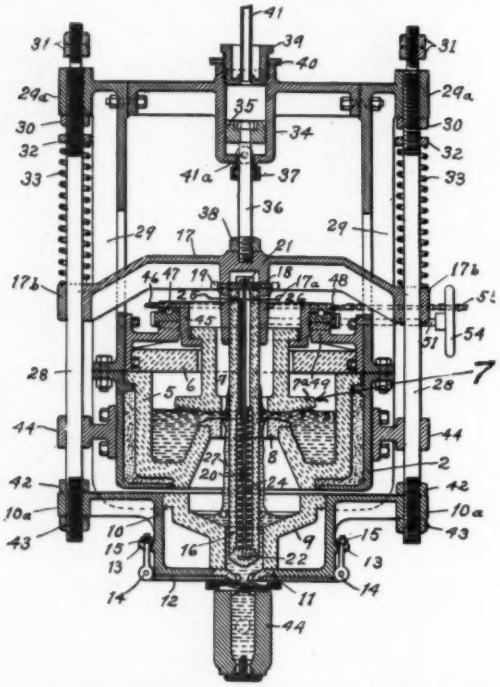


Fig. 3. 2,305,739: Shackleford. In a feeding arrangement, flow of glass into the well is retarded and controlled by the speed and depth of immersion of a refractory rotor 7.

Miscellaneous Processes

The Hood-Nordberg process by which Corning Glass Works produces highly siliceous glass articles was dealt with at length in the November 1940 issue of The Glass Industry. This process, as described in their patent 2,106,744 comprises melting a glass, fabricating it into a fixed shape, heat treating the shaped article to separate the glass into a soluble and an insoluble phase, or in other words, to make soluble a major portion of the constituents other than silica, dissolving out the soluble phase or constituents to leave a highly siliceous, rigid, porous structure having the same shape as the initial article, and firing the resultant article to close the pores and form a vitreous transparent glass. Such glass has a silica content of over 93% and a thermal expansion coefficient only slightly above that of pure vitreous silica. As shown in the patent, any coloring oxides or agents present in the initial glass are substantially removed during the process and the final glass is practically colorless.

Now Nordberg (Martin E.) and Harold E. Rumenapp have been granted a patent 2,303,756 in which various means of decorating the ware are discussed. They have found that after the ware has been leached and washed its highly porous condition can be taken advantage of by introducing a solution carrying a metal coloring salt. Then when the ware is given the shrinking heat treatment the color is developed. If the whole article is to be colored it need only to be immersed in a solution of the desired salt. If the colored area is to be restricted the leached and washed article is first dried and then the metal salt solution is applied in the desired design by means of a brush or a silk screen or the like. To confine the spread of the metal salt solution, its viscosity may be increased by adding glycerine.

An automatic screen stencilling machine is described in patent 2,304,725 assigned to Libby Glass Co. by Thomas S. Bauman of Toledo.

Fig. 4 shows the ingeneous arrangement and shaping of deflectors in a ware stacker for aligning articles fed to a lehr, described in patent 2,304,379 granted to Raymond A. Senkbeil of Baltimore and Chas. H. Knickman of Catonsville, Md. (Maryland Glass Corp.) The ware is delivered in single file down the center of the conveyor above whose surface the winged deflectors are spaced. The deflectors are free to be swung about 45° as indicated by the dashed lines. When an article, d, strikes the center deflector it is shunted to one side or the other and in turn swings the deflector so that the next article will be shunted to the opposite side. The advancing ware strikes the one stationary deflector 67 and then moves on to other swinging deflectors similar to the first. It will be seen that the result will be to give the articles a regular spacing as they enter the lehr.

Two patents for apparatus intended for severing glass tubing into predetermined lengths are 2,306,721 issued to Samuel A. Forter and Harold H. Snyder of Pittsburgh, (Forter-Teichmann) and 2,304,926 issued to James W. Juvinall of La Grange, Ill. (Western Electric Co.). In the former apparatus the tube is advanced continuously, while the cutting tool (abrasive wheels) moves with it and also moves circumferentially around the tube to make the cut. In the Juvinall apparatus a group of spaced tubes are set up with their ends overhanging a rubber support which hold them. A rotating cutting wheel moves across them in a way which nicks only their bottom faces in such a manner that a vibration is set up which causes them to snap off.

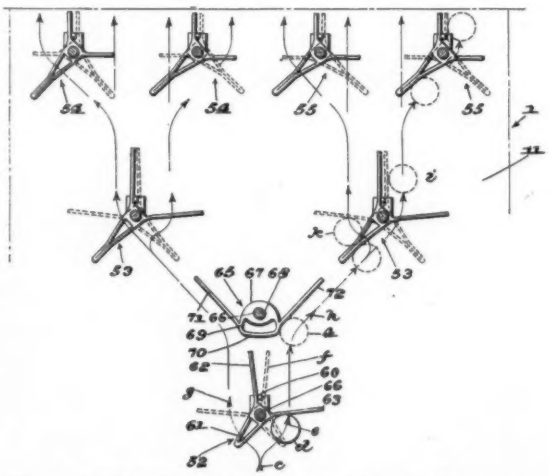


Fig. 4. 2,304,379: Senkbeil and Knickman. Ware stacker to provide regularly spaced articles to a lehr.

Edwin M. Guyer of Corning, N. Y. has obtained a patent 2,306,054 (Corning Glass Works) which covers many methods of locally heating glass tubing or other articles by electricity so that they can be sealed, sepa-

rated or similarly worked. By one method fine-tipped gas flames would provide an initial heating to render the glass conducting so that an electric current would be more effective. A comprehensive discussion of the factors involved in heating glass electrically is found in this patent.

Another Corning Glass patent is 2,304,142 granted to Fred A. Bickford for a glass filter tube containing a sintered glass filter plate.

Patents 2,304,436 and 2,304,437 granted to Wm. D. Bell of Columbus, Ohio (Anchor-Hocking Glass Co.) concerns machinery for feeding caps to fruit jars to be packed.

A method of continuously drawing thermometer or capillary tubing by progressively melting the end of a glass rod is described in patent 2,306,995 issued to Chas. R. Palmer and Curtis P. Mitchell of The Palmer Co., Norwood, Ohio.

Sheet and Plate Glass

Two patents involving mirror manufacture are 2,306,318 granted to Wm. Owen of Pittsburgh Plate Glass Co. and 2,305,346 to John J. Hopfield of Libbey-Owens-Ford Glass Co. Owen applies the mirror solutions to the top of a glass plate while sprays of water cover the bottom surface to prevent it being touched by the solutions. Hopfield finds that the reflecting surface is improved by applying pressure to the ductile metallic coating after it has been applied.

In a machine for drawing a glass sheet from a forehearth, L. B. White and F. S. Tharp of Clarksburg, W. Va. (Pittsburgh Plate Glass Co. 2,303,805) introduce a heat absorbing block on each side of the sheet above the drawing surface. The normal action of the water coolers is to cause the central portion of the sheet to be thicker than the edges. Therefore this patent so designs the heat absorbing refractory blocks as to have a greater mass in the center for absorbing heat from the forehearth, and thus to minimize the normally greater cooling effect in this section of the sheet.

Other Pittsburgh Plate Glass Co. patents are 2,306,314 issued to M. D. Lardin of Tarentum, Pa. and 2,303,885 to R. A. Miller and Wm. O. Lytle. Lardin is concerned with the correction of imperfections in laminated sheets characterized by a parting along the edge where satisfactory contact has not been established between the plastic and one or both sheets of glass. The corrective method is to lay a strip of plastic along the edge, place the plate in a rubber bag which is evacuated and the bag subjected to heat and pressure. This is said to effect a union between the plastic strip and the defective plastic interlayer so that a perfected article is obtained. Miller and Lytle produce a laminated sheet made of layers including one or more of cellulated foam glass. They spread a thin layer of a refractory dust on a continuous conveyor surface, form a molten sheet of glass upon it, deposit a layer of powdered glass plus gas-forming agents on the molten sheet, and heat to form the gas and to sinter the cellular top layer.

Bernard Long's latest patent 2,303,749 (The American Securit Co.) reveals new techniques in tempering glass sheets. The air quench is provided through slits which give sheets of air projected entirely across the width of the glass sheet. After the passage of a number of the air sheets by moving the glass past the slits, final cooling may be provided through ordinary grilled openings.

In patent 2,305,683 which has been taken over by the Alien Property Custodian, Bernhard Engels of Germany describes a method of continuously producing multilayer flashed glass. A flashing glass is applied against a cooler and thicker base sheet having a higher melting point, whereby the flashing glass is cooled locally and adheres to the base in a thin layer; the flashing sheet having a higher expansion coefficient than the base the result of cooling is to cause the flashing layer to shrink more and to apply increased compressive stresses to the base.

Other patents involving sheet glass are 2,305,405 to C. D. Burrell of Libbey-Owens-Ford Glass Co. and 2,305,827 to Adolf Kampfer of Berlin, Germany (vested in the Alien Property Custodian). The first involves clamping means for securing two oppositely inclined stacks of glass sheets. The latter is concerned with the preparation of plastic sheets for laminated glass.

Glass Wool and Fiber

Games Slayter of the Owens-Corning Fiberglas Corp. received patent 2,306,347 for methods of making thin sheets of webbed or matted glass fibers. The fibers blown down into a collecting head in haphazard fashion are picked up or drafted from it onto a roll or similar device which aligns the fibers to a certain extent. A binder is applied in some manner as by drawing the drafted sheet through a trough. Patent 2,304,233 assigned to the same company by W. M. Bergin and A. L. Simison describes a method of insulating odd shaped units such as stove door panels with glass wool containing a thermo-setting bond which is set up hard by baking the entire panel. This might even be accomplished in the heating process by which a ceramic enamel is baked onto the panel.

Charles S. Francis Jr. of Chestnut Hill describes in patent 2,306,781 assigned to Sylvania Industrial Corp., a method of making yarn by twisting together a combination of glass fibers and organic fibers such as those of a polyvinyl acetate. When heated the latter soften and tend to unite with the glass fibers at points of contact.

REVISE STOCK BOTTLE STANDARDS

Copies of the revised Simplified Practice Recommendation R123-30 for Carbonated Beverage Bottles have been sent to bottlers, bottle manufacturers and other interested groups for their consideration by the National Bureau of Standards.

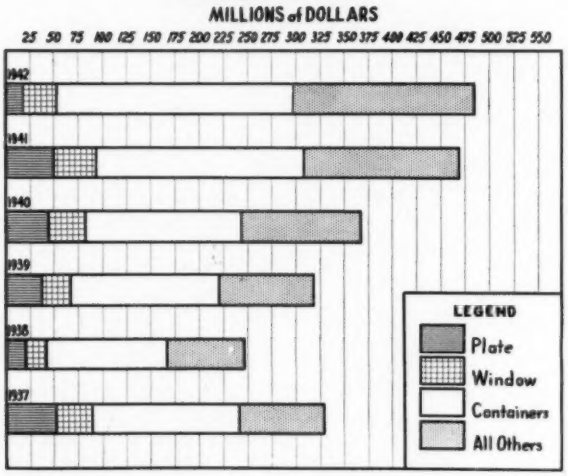
This current revision of the original recommendation promulgated in 1930, which covered standard capacities, dimensions and weights of glass for each bottle, was approved by the Industry Advisory Committee of the War Production Board. Since the cooperation of the industry is necessary to the success of the recommended program, the Division of Simplified Practice is anxious to get the approval of the manufacturers themselves as soon as possible.

The proposed simplified list of standards relates only to the non-returnable type of bottles, those stock bottles having no lettering molded or permanently applied thereon to indicate ownership of the container or origin of the product contained in them.

CURRENT STATISTICAL POSITION OF GLASS

THE GLASS INDUSTRY'S INDEX

Production: Twelve Months, January Through December



During December production in the glass industry remained at the same level as November with no change in the total employment nor payroll figures. According to The Glass Industry Production Index output during December came to $40,000,000 a slight decrease from the December 1941 figure. This brings the 1942 total production up to $485,000,000, a $15,000,000 increase over last year's production figures. The figure for 1942 shows the greatest output in the glass industry since 1937.

Plate glass production during December amounted to 5,000,723 sq. ft. according to the Plate Glass Manufacturers of America. This was an increase of 8 per cent over November's total, but a decrease of 51 per cent from December, 1941's, level. During the 1942 twelve-months' period plate glass production dropped 67 per cent from 1941's 12 months total of 190,403,613 sq. ft. to 62,248,897 sq. feet. This was the lowest plate glass output since the depression year of 1932 when the total for the year was 52,221,635 sq. ft. The stoppage of certain industries due to war needs has been a contributing factor to this decline.

Window glass production for the month of December was 1,296,796 boxes, only a 2 per cent decrease from the total for December, 1941, which was the largest monthly output in the history of the industry. December's total was also an increase of 38 per cent over November's level. During the 12 months period for 1942 the industry showed a total of 15,789,173 boxes, a 3 per cent decrease from the figure for the same time in 1941.

Glass container production during December amounted to 6,268,011 gross as reported by the Glass Container Association of America. This figure showed a slight increase over the November total and 3 per cent over the amount given for December, 1941. The cumulative figure for the year 1942, 78,640,999 gross, was the largest output in the history of the glass container industry, topping its record level in 1941 by 12 per cent.

Shipments of glass containers during December totalled 6,528,034 gross, a 31 per cent increase over December, 1941, and a 4 per cent increase over November's level. Shipments during the year 1942 reached the highest level in the history of the industry, showing an increase of 14.53 per cent over 1941's total.

Gains among glass containers over December, 1941, were: fruit jars—285 per cent; beer bottles—101 per cent; narrow neck food containers—93 per cent; wide mouth food containers—91 per cent. Outstanding increases in the 12 months period in 1942 over 1941 were revealed in beer bottles, 102 per cent, fruit jars, 66.97 per cent and wide mouth food containers, 34.32 per cent.

Inventories of glass containers were 19 per cent lower at the close of the year 1942 than they were at the close of 1941, the total for December being 7,773,899 gross.

Miscellaneous glass products manufactured in December were valued at $16,000,000, a decrease of 5 per cent from November's total and approximately 10 per cent from December, 1941's figure. Production in this branch of the industry for the year 1942 totalled $188,000,000 as compared to $164,000,000 for 1941, a 14 per cent increase. There has been a steadily rising increase

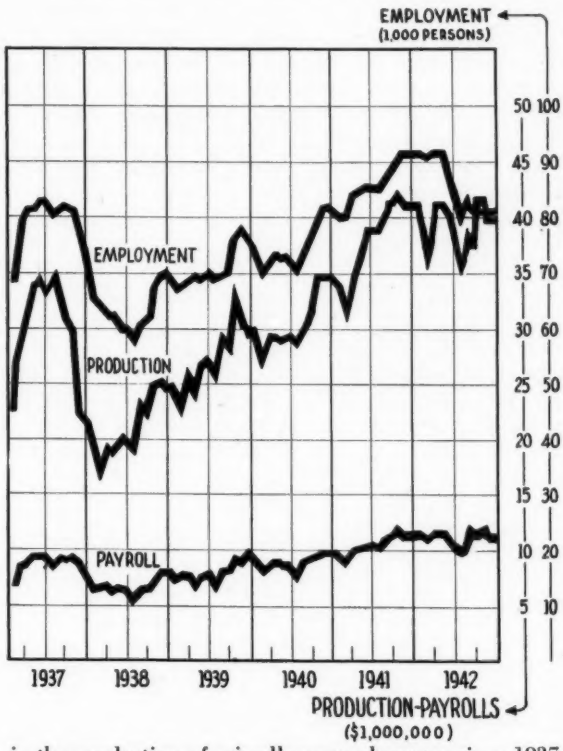
CURRENT GLASS CONTAINER PRODUCTION

(All Figures Are Gross)

	Production		*Shipments*		*End of Month Stocks*	
Classifications	*Dec. 1942*	*Dec. 1941*	*Dec. 1942*	*Dec. 1941*	*Dec. 1942*	*Dec. 1941*
Food Containers	1,986,307	1,317,834	2,172,062	1,114,460	1,955,978	2,372,917
Pressure and Non-Pressure Ware (Narrow Neck, Wide Mouth and Pressed)	363,438	387,686	362,109	332,469	333,591	600,592
Beer Bottles	742,669	409,702	813,800	395,490	311,840	386,457
Liquor Ware	843,754	1,027,050	861,941	843,146	1,482,235	1,942,881
Medicine and Toilet Ware	1,452,635	2,040,682	1,491,120	1,640,268	2,496,669	3,044,491
General Purpose	522,772	436,015	515,964	374,058	589,042	452,724
Milk Bottles	246,645	271,758	271,824	244,567	330,344	367,521
Fruit and Jelly	85,889	133,159	15,551	4,266	243,910	400,641
All Other	23,902	18,775	23,663	16,036	30,290	41,920
Total Industry	6,268,011	6,042,661	6,528,034	4,964,760	7,773,899	9,610,164

GI THE GLASS INDUSTRY'S INDEX

Monthly Trends Through December, 1942



in the production of miscellaneous glassware since 1937, which reached its highest point in 1942.

Automatic tumbler production during December totalled 3,836,506 dozens, or an 11 per cent decrease from 1941's comparable month. 1942's total production of this glassware amounted to 50,951,281 dozens, a decrease of 3 per cent from the previous year's figure. Shipments during December increased 15 per cent over December, 1941, to 3,746,498 dozens, bringing the year's total slightly under 1941's volume to 50,868,246 dozens. At the close of 1942 finished stocks of tumblers showed a decrease of 19 per cent from 1941's level to 7,177,226 dozens.

Manufacturers sales of machine made table and kitchen and household glassware during December amounted to 3,744,377 dozens, an increase of 46 per cent over the same month in 1941. Total sales for the full year of 1942 were 38,585,772 dozens, a one per cent decrease from 1941's comparable figure.

Employment and payrolls: the glass industry employed 81,000 persons during the month of December, showing no increase over the number reported for October and November. This is a 12 per cent decrease from the number of people reported employed in the industry during December, 1941.

Payrolls in the glass industry during December amounted to $11,500,000 keeping the same level as in November. During the year 1942 glass manufacturers paid out about $142,500,000 in wages compared to $135,000,000 in 1941. Figures show that this yearly figure is the highest since 1937.

J. T. & A. HAMILTON BECOMES NEW KNOX UNIT AS SEABOARD GLASS CO.

One more unit was added to the constantly growing Knox group of glass container plants through the acquisition of J. T. & A. Hamilton Company of Pittsburgh by Knox Glass Associates, Inc., effective February 1, 1943.

The new Knox factory will be known as the Seaboard Glass Company, operating independently as do other Knox affiliates, but in reality is the Pittsburgh unit of the Seaboard Glass Company of East Stroudsburg, Pa. Incorporation of the Stroudsburg company, a Knox enterprise, took place in 1942 but construction of the plant has been placed in abeyance for the duration.

Various plant improvements in the newly acquired Pittsburgh factory are contemplated. Repairs on its large furnace will be immediately undertaken. When this work is completed similar work will be done on the smaller tank. Production will be maintained to the extent of available facilities while the furnace repair work is being completed, and the company plans the same tonnage as heretofore produced. After furnace changes are made there will be 9 machines in operation and eventually major improvements in plant layout will be undertaken.

Production of milk, wine and liquor bottles and cosmetic containers will continue with possible expansion of the line into other fields at a later date. Sales of all lines of ware will be handled exclusively by Knox Glass Associates, Inc., of Oil City, Pa.

Announcement is made of the retirement of James W. Hamilton and Albert G. Hamilton, formerly president and vice president and treasurer respectively. James Telford Hamilton, however, will remain active with the new company as vice president and plant manager. All other officers of the company are Knox men; they are: R. R. Underwood, president; E. A. Schrag, vice president; L. D. Richardson, secretary-treasurer; I. L. Bachmann, assistant secretary and assistant treasurer; directors, R. R. Underwood, E. A. Schrag, H. C. Rose, C. R. Deible, A. L. Steck, and L. D. Richardson.

• Uranium and its compounds for use in glass, pottery, tile and other ceramic products were forbidden by Conservation Order M-285, issued by the Director General for Operations. After January 26 the sale, delivery and purchase and receipt of this chemical for ceramic use are prohibited. Increasingly important war uses make it necessary to conserve supplies and stop relatively non-essential consumption.

• W. I. Galliher, formerly Director of Sales of the Pittsburgh Plate Glass Company's Columbia Chemical Division, has been appointed Executive Sales Manager of the Division to succeed Eli Winkler, who has been retained in the capacity of Executive Consultant.

• Mr. Gene Cunningham has been added to the furnace engineering department of the Owens-Corning Fiberglas Corporation, Newark, Ohio.

• Mr. H. J. Tait, Works Manager of the Holophane Company, Inc., Newark, Ohio, who has been confined to his home for the past six months with a serious illness, is recovering rapidly and will return to his office in the near future.

GLASS GAGES . . .

(*Continued from page 69*)

material advantage, in that, the parts gaged vary widely as to this factor. On the other hand, no such flexibility is possible with the steel used in gages, as its coefficient of expansion is definitely set at .000006 in./in./1 deg. F.

Directly related to this characteristic is the fact that the lower the coefficient of expansion of glass, the greater is its hardness and stability against chemical attack and weathering in a humid atmosphere. Naturally, hardness and a high wear resistance is a "must" for gages regardless of the material from which they are made. Experience has already proved that glass gages are the equal, if not the superior, of steel gages from the standpoint of wear.

In gauging, it is almost impossible to avoid scratching entirely, especially in certain types of work. Scratches on steel gages raise burrs which increase their size and permits them to pass offsize parts. While glass will also scratch, no burrs are raised thereby, and their usefulness remains unimpaired. Rust is another detriment to steel gages, and careful attention must be paid to their greasing every time they are put into temporary storage or shipped, and cleaning when put back into use again. On the other hand, there is no rusting with glass gages nor does perspiration etch them.

Greater visibility of gauging is possible with glass gages and they are light and more easily handled than are steel gages. Also seizing or galling, which is particularly noticeable when gauging copper or brass components with a steel plug gage, is lacking when using glass gages. These factors have speeded up the work of gauging on some parts by as much as 50 per cent.

In order to achieve the greatest mechanical strength possible, glass gage design is varied slightly from that used in the making up of steel gages. While the strength of glass in compression is usually in excess of 100,000 lbs. per sq. in., its tensile is down to between 5000 and 15,000 lbs. per sq. in. Therefore, increased area in many cross sections are incorporated in their design. Also, all exposed edges must be beveled or finished to a radius to minimize chipping or breakage when dropped or handled roughly.

Glass manufacturers who have already furnished the Ordnance Department with gages include, the Corning Glass Works, Corning, New York; the A. S. Heisey Company, Newark, Ohio; the Fischer & Porter Company, Hatborough, Pennsylvania; the T. C. Wheaton Company, Millville, New Jersey, and the Specialty Glass Corporation, Newfield, New Jersey. Among glass makers who may also be employed in the manufacture of glass gage blanks are the following: the Libbey Glass Company, Toledo, Ohio; the Sneath Glass Company, Hartford City, Ind.; the Duncan & Miller Glass Co., Washington, Pa.; the Federal Glass Company, Columbus, Ohio; the Anchor Hocking Glass Corp., Lancaster, Ohio, and the Jeannette Shade & Novelty Co., Jeannette, Pa.

One glass concern has designed a complete line of plug and ring blanks to correspond with the American gage design steel blanks as outlined in Commercial Standard, CS 8-41. Both molding technique and the functional use of glass gages were carefully considered while developing these designs. This is one of the most constructive moves in the glass gage field yet made within the glass industry.

The burden of educating the steel gage manufacturers in the proper methods of finish grinding the blanks will also fall on the shoulders of the glass industry. The service will include furnishing glass blanks with precision centers for final grinding at steel gage factories. This can be readily done as many glass companies have already developed considerable technique in such machines and could readily apply it to centering the gage blanks. It is quite possible that the glass companies making gage blanks, would be called upon to do some rough grinding because of the diameter variation inherent in molding. They should also be in a position to advise steel gage makers as to the grinding wheel composition, grinding speed, coolant and method of final lapping as applied to the particular type of glass blank they are supplying.

A direct comparison was recently made between a glass and a steel gage used on identical work, a medium size artillery cartridge case. The glass gage had checked approximately 163,000 cases without perceptible wear, not even as much as 0.00005 in. wear, which was quite remarkable. The steel gage had checked about 800,000 cases and showed a wear of 0.0007 inch. Particular attention is directed to the fact that the glass gage was originally almost up to maximum of tolerance permitted and the steel gage was to the maximum tolerance. This makes the comparison all the more striking. This particular function is a real test for any gage inasmuch as the component is drawn, not machined, and the gage has to round up the mouth of the cartridge case. A drawn cartridge case is not perfectly round at the mouth. Furthermore, it is to be noted that brass is much harder on a gage than steel, inasmuch as brass has a tendency to lap the gage.

MEXICO AGREES TO REDUCE EXPORT DUTIES IN TREATY WITH U. S.

The three-year reciprocal trade agreement between Mexico and the United States, which included the reduction of duties on several glass products and the binding of existing duties on others, went into effect on January 30, 1943, thirty days after the proclamation by the Presidents of the United States and the United Mexican States.

Mexico has agreed to bind its duties on high grade American glassware, guaranteeing not to increase the present tariff. Duties on certain types of glass were reduced 50 per cent. The export duty from Mexico of "bubble glass" formerly was 60 per cent ad valorem and will now become 30 per cent ad valorem.

"Bubble glass" as described in the Treaty consists of "articles of every description not especially provided for, composed wholly or in chief value of glass, blown or partly blown in the mould or otherwise, or colored cut engraved, etched, frosted, gilded, ground (except such grinding as is necessary for fitting stoppers or for purposes other than ornamentation), painted, printed in any manner, sandblasted, silvered, stained or decorated or ornamented in any manner whether filled or unfilled, or whether their contents be dutiable or free (except articles if cut or engraved, valued at not less than $1 each); any of the foregoing commercially known as bubble glass, if produced otherwise than by automatic machine."

(*Continued from page 71*)

verted the complex expressions into more convenient forms and have listed the new constants involved in tabular form for more convenient use. The authors have been quite kind to those technologists that shy at elaborate mathematical procedures, having set aside several pages of the paper which include only the necessary equations and simple details for their use.

This section of the paper should be referred to by those technologists that include density determinations along with their chemical analysis. The calculation of density from the chemical analysis gives a fairly good check on the accuracy of the chemical analysis.

OLEAN, THATCHER COMPLETE CONSOLIDATION

Consolidation of the manufacturing operations of Olean Glass Company with those of its parent company, Thatcher Manufacturing Company, in the process of development during the past year, has been completed and on January 1 Olean became a definite part of Thatcher.

Walkerman D. Dugan, who a year ago was appointed Vice President in Charge of all Thatcher manufacturing operation, has resigned as mayor of Olean in order to take up residence at headquarters in Elmira. While the Olean plant will henceforth be operated on the same basis as the other Thatcher units, the sales activities remain the same with the Olean Glass Company, Inc. continuing to market general line container ware under the direction of Mr. Franklin B. Pollock.

WISHART REPLACES MOREY IN PARKERSBURG

The Corning Glass Works has announced the appointment of Dr. Arthur W. Wishart as General Manager of the company's new plant at Parkersburg, W. Va.

Dr. Wishart succeeds Dr. George W. Morey, eminent glass scientist. Dr. Morey, a year ago, was granted a leave of absence from the Geophysical Laboratory of the Carnegie Institution of Washington to get production started at the Corning plant. Dr. Morey has announced that he is leaving the Corning organization to return to Washington, where he will take charge of a research problem under the National Defense Research Committee.

Dr. Wishart received the degrees of B.Ch. and Ph.D. from the University of Minnesota, where he studied in the fields of Physics and Physical Chemistry.

He joined the Research Division of the Corning Glass Works in 1940, later being attached to the Optical Glass Department and to the staff of the Chief of Glass Technology. Since the opening of Corning's Parkersburg plant, and until his new assignment as General Manager, he has served as Technical Director under Dr. Morey and has been active in developing the plant's technical facilities and staff.

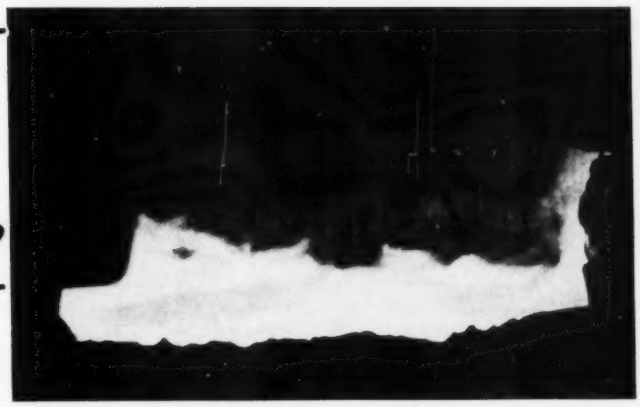
• In reporting Donald E. Sharp's election to the Society of Glass Technology in the January issue of The Glass Industry the names of four Americans previously elected to fellowship in the Society were inadvertently omitted from the item. They are Dr. E. C. Sullivan, Dr. A. L. Daly, Dr. Alexander Silverman and Dr. Ross C. Purdy.

GET ALL 3

WITH TYPE SAL NATIONAL AIROIL OIL BURNERS

VELOCITY
LUMINOSITY
ECONOMY

The Type SAL National Airoil Oil Burner shown here is an ideal choice for firing Glass Tanks or Sodium Silicate Furnaces. Can be efficiently operated with either steam or compressed air for atomization, at a wide range of pressures. Now in service in numerous glass plants. *For more details, write us.*



Above is an unusual photograph taken through an observation hole in a glass tank fired by Type SAL Burners. Notice the rolling, luminous flame sweeping close to the surface of the glass.

NATIONAL AIROIL BURNER

We make: Oil Burners, Gas Burners, Gas Pilots, Oil Pump and Heater Sets, Explosion Doors, Access Doors, Air Doors, Burner Blocks, Furnace Observation Windows.

COMPANY, INCORPORATED
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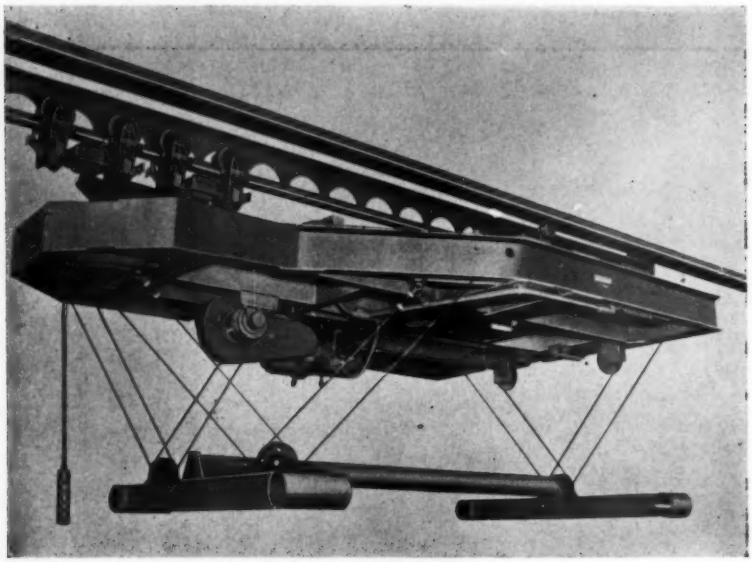
NEW EQUIPMENT AND SUPPLIES



NEW STABILIZED CARRIER SOLVES HOISTING PROBLEM

One of the oldest problems in hoisting has been solved by the Cleveland Tramrail Division of The Cleveland Crane & Engineering Company in their new Stabilized Tramrail Carrier by suspending a load rigidly with the use of the usual flexible hoisting ropes.

The rope angles have been worked out according to a mathematical formula so that the ropes form a triangular suspension, which holds a load rigidly in place, eliminating longitudinal, lateral and rotational sway. The load can be raised or lowered for a considerable distance and still remain rigid. The carrier will also support an unbalanced load without any swaying, and will allow it to be tilted or rotated in either direction.

The stabilized carrier may be operated on two standard Cleveland Tramrails or on a double girder Tramrail crane bridge. This arrangement keeps the carrier level at all times regardless of type of load or its position.

These carriers have been built for capacities of one, three, and five tons, some hand-propelled and some electrically propelled, but all with motor-driven hoist.

FUSE-BOND PROCESS

Machine components and similar metal parts may be prepared for metallizing electrically by a new Fuse-Bond Process developed by the Metallizing Engineering Co., Inc. The process has the advantage of providing an adequate bond on the hardest surfaces, up to the present time impossible or impractical to prepare by blasting or rough threading.

The process is applied with the Metco Fuse-Bond Unit, operating on any 110 or 220 volt, single phase power line. This equipment fuses a rough deposit of electrode metal into the surface to be metallized. Electrodes are applied to the work with a special holder which uses up to six electrodes at a time.

The weight of the unit is 170 lbs. and is contained in a cabinet measuring only 24 inches high. All attachments fit into a bin in the top of the cabinet and it can be wheeled to the job on attached casters.

ELECTRONIC DRIVE

A new electronic variable speed drive has been introduced by General Electric which is ideally suited for many industrial applications because of the adjustable-voltage electronic control system, called Thy-mo-trol. This system in combination with a suitable motor provides a drive that has many features not usually found in other drives.

The standard drive of this type consists of an anode transformer, a control and rectifier panel, a push-button station and a d-c driving motor. The accelerating scheme, called constant-current limit acceleration, is capable of starting its load with a minimum of shock to the machine and will permit the motor to comutate satisfactorily.

Protection against sustained overload is provided by means of a conventional thermal overload relay, and the motor is stopped quickly by a dynamic breaking. Another feature of the Thy-mo-trol system is a "voltage-snubbing" circuit which automatically keeps the voltage down to a safe value. The motor speed-range has been tested and proved to operate over a range of up to 20 to 1 below base speed by armature control on an intermittent basis without exceeding a dangerous temperature rise.

Circuits have been so designed in the system that the equipment is entirely safe regardless of which tube or combination of tubes may fail. The equipment will either shut down instantly or will continue to operate.

CATALOGS RECEIVED

Leeds & Northrup Company, Philadelphia, Pa. Automatic control equipment for control of temperature, pH, conductivity or per cent SO_2 is the subject of a 29-page catalogue recently published by Leeds & Northrup. The equipment is explained in detail and extensive diagrams are included.

General Electric Company, Schenectady, N. Y., has published a booklet on "How Industrial Plants Can Increase Power Capacity." By installing their capacitors, the booklet states, plant circuits can carry more load with no increase in the total current demand.

Solvay Sales Corporation, New York, N. Y. A 30-page reference manual of Solvay products has just been put out by the Solvay Sales Corporation, giving specific information on forms and the chemical and physical properties of the products and their uses. In addition there are short chapters on safety methods.

General Electric Company, Schenectady, N. Y. The great scope of electronics is described with colorful words and illustrations in a new booklet issued by General Electric. Called "Electronics—A New Science for a New World," it shows pictorially the unbelievable present-day uses of the tiny electron and tells of the future possibilities of this particle of electricity.

Wheelco Instruments Co., Chicago, Illinois. Five new bulletins have just been released by Wheelco describing its complete line of industrial indicating, recording and control thermometers. The booklets are well illustrated.

ERNEST HOMMEL BURNED BY PLANT EXPLOSION

Ernest O. Hommel, president of the O. Hommel Company, is in the Pittsburgh Hospital recovering from burns on face and hands received from an explosion in his plant. The accident occurred on January 22 while Mr. Hommel was walking through the plant on an inspection trip. He and four others, who were also in the vicinity at the time, were taken to the hospital, and from last reports all of the injured were making a rapid recovery. The machinery damage has been repaired, and the department resumed its operations after three days' delay.

BALL BROTHERS ACQUIRE ARIDOR CO.

The Aridor Company, Chicago, Illinois, manufacturers of closures for glass containers, announce that ownership of the company is now held by Ball Brothers Company of Muncie, Indiana. The Aridor Company will continue to function as an independent unit in the manufacture and sale of caps. No change in management is contemplated; Colonel R. G. Peck remains as president and R. G. Peck, Jr., as vice-president and sales manager.

• Members of the American Forces stationed in Australia who are interested in glass have been cordially invited by Mr. T. C. Moorshead, Director of the United Glass Bottle Manufacturers, Ltd., at Bickley, Kent, to visit any of their factories, according to a letter received by Francis C. Flint of the Hazel-Atlas Glass Company.

Help Wanted . . .

Required April 1st several Continuous Glass Tank Teasers.

Required April 1st several Tube Drawing Mandrel Furnace Operators.

Required At Once. Analytical Chemist for silica analysis in modern Glass Plant.

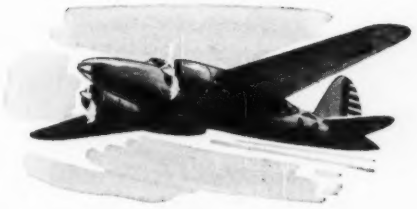
Required At Once. One Technician for Glass Plant Control Laboratory work. Required: Several machine mechanics for maintaining work. Must be familiar with glass making machinery.

Continuous Glass Operating Plant with Day Tanks requires the services of one foreman familiar with furnace operation and two Tube Drawing Room foremen.

Address replies to Box 55
THE GLASS INDUSTRY
55 West 42nd Street, New York, N. Y.

THIS LITTLE PIECE
OF DOLOMITE LIMESTONE

IS SERVING THE
WAR EFFORT



The new *magnesium metal*, made from dolomite limestone, is contributing to the production of essential war needs.

The combined qualities of lightness, strength and durability make magnesium metal desirable for the metal skin of warplanes, castings for cylinders, pistons and other parts.

Today, most of the entire output of the Banner Quarries is going into essential war production . . . STEEL, AGRICULTURE, BUILDING and GLASS . . . and now Banner contributes to the production of another number one War Essential . . . MAGNESIUM METAL.

THAT'S WHY *Banner-Lime* IS
Essentially yours

NATIONAL MORTAR AND SUPPLY COMPANY
Grant Building, Pittsburgh, Pa.
Since 1907 . . . A good company to do business with

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	50.00	55.00
Precipitated material		55.00	60.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00–16.00	18.00
Borax ($Na_2B_4O_710H_2O$) Granulated	In bulk, ton	42.50	....
Granulated	In bags, ton	46.00	56.00–61.00
Powdered	In bags, ton	51.00	61.00–66.00
Boric acid (H_3BO_3) Granulated	In bulk, ton	96.50	
Granulated	In bags, ton	100.00	111.00–116.00
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.09½–.09¾	.10
Synthetic (Artificial)	lb.	No supplies available.	
Feldspar—(published list prices) 20 mesh	ton	11.00–13.25	
40 mesh	ton	11.50–13.75	
Granular	ton	11.75–14.00	
Semi-granular	ton	11.00–13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags.			
Fluorspar (CaF_2) domestic, ground, 96–98% (max. SiO_2, 2½%) Bulk, carloads, f. o. b. mines	ton	34.00	....
In bags	ton	36.40	50.00
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.0900	....
In 5 Ton lots	lb.	....	.0950
Less than 5 Tons	lb.	....	.10
Lime— Hydrated ($Ca(OH)_2$–MgO) (in paper sacks)	ton	8.50	9.50
Burnt (CaO–MgO) ground, in bulk	ton	7.50	....
Burnt, ground, in paper sacks	ton	9.50	9.50
Burnt, ground, in 191 lb. gross drums	Per drum	1.70	1.80
Kiln Dried ($CaCO_3$–$MgCO_3$) 10x30 mesh	ton	2.00	....
Kiln Dried ($CaCO_3$–$MgCO_3$) 16x120 mesh	ton	2.00	....
Nepheline Syenite, f. o. b. shipping point	In bulk, ton	12.00	15.00
Potassium carbonate— Calcined (K_2CO_3) 96–98%	lb.	.065	.0675
Hydrated 80–85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4) in bags	ton	21.00–22.00	28.00–30.00
in bulk		17.50	
Soda ash (Na_2CO_3) dense, 58%— Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In Paper bags	Per 100 lb.	1.10	
In Burlap bags	Per 100 lb.	1.15	....
Sodium nitrate ($NaNO_3$)— Refined (gran.) in bbls	Per 100 lb.	....	3.00–3.40
95% and 97% Bulk	Per 100 lb.	1.35	2.50–3.00
200 lb. bags		1.4675	....
100 lb. bags		1.5025	....

Special Materials

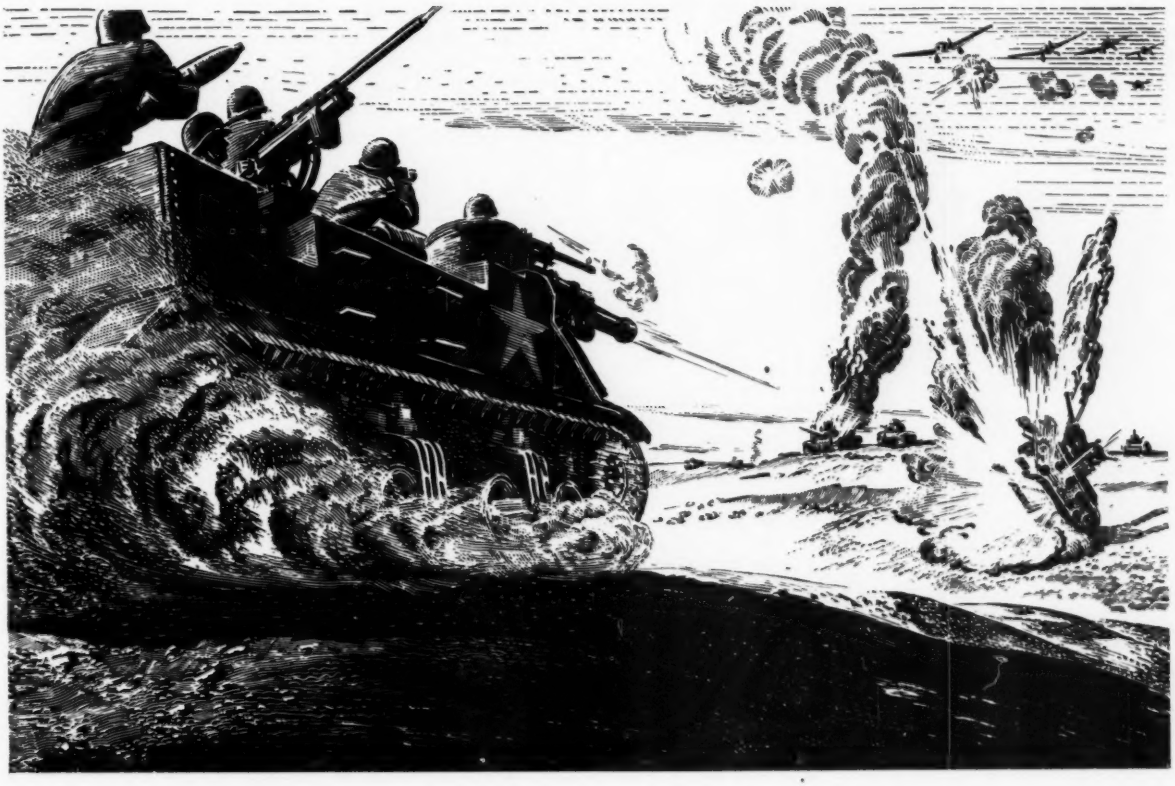
		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	.031–.034	.045
Aluminum oxide (Al_2O_3)		.07	.09
Antimony oxide (Sb_2O_4)	lb.	Open price	.15½–.17½
Arsenic Glassmakers	lb.	.04¼	.04¾
Regular refined white	lb.	.04	.04½
Arsenic trioxide (As_2O_3) (dense white) 99% In barrels		.04–.04¼	.04½–.04¾
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	Open price.
Pyrophyllite (20% Al_2O_3)	ton	10.00	13.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.05	.06–.06½
Tin Oxide (SnO_2) in bbls	lb.	....	Open price.
Titanium Oxide (ceramic grade) In bags	lb.	.14½	....
In barrels	lb.	.14¾	....
Zinc Oxide (ZnO) American process, bags	lb.	.07¼	.07½
White Seal, 150 lb. bbls	lb.	.09¾	.10
Green Seal, bags	lb.	.09	.09¼
Domestic White Seal, bags	lb.	.09½	.09¾
Red Seal, bags	lb.	.08½	.08¾
Zircon Refined Granular (Milled .01–.02c higher)		.03½	.04¼

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40–1.60
(Commercial, 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	1.10–1.15
Cerium hydrate— 600 lb. barrels	lb.	....	.65
Chrome Oxide Green, 400 lb. bbls	lb.	....	.25–.28
Chromite (99% through 200 mesh)	ton	58.25	64.75
Chromite ore (air floated)	ton	58.25	64.75
Cobalt oxide (Co_2O_3) In bbls. 350 lbs. or more	lb.	....	1.84
Less than 350 lbs.	lb.	....	1.94
Copper oxide— Red (Cu_2O)	lb.	....	.20–.22
Black (CuO)	lb.	....	.19–.22½
Black prepared	lb.	....	Open price.
Iron Oxide— Red (Fe_2O_3)	lb.	....	.06½–.10
Black (Fe_3O_4)	lb.	....	....
Iron Chromate	lb.	....	.035–.05
Lead Chromate ($PbCrO_4$) in bbls	lb.	....	.16
Lithium Carbonate	lb.	....	1.25
Manganese, Black Oxide African In Paper bags	ton	70.00	78.00
In Burlap bags	ton	71.75	79.75
In Casks	ton	74.00	82.00
Neodymium oxalate, 50 lb. drums	lb.	....	4.00
Nickel oxide (Ni_2O_3), black	lb.	....	.34–.40
Nickel monoxide (NiO), green	lb.	....	.35–.37
Potassium bichromate ($K_2Cr_2O_7$)— Crystals and Granular	lb.	.09½	.09¾–.10
Powdered	lb.	....	.10¼–.10½
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.21–.25
Rare earth hydrate— 100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) in 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.07¼	.07½–.07¾
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08¼	.08⅞–.09¼
Sodium selenite (Na_2SeO_3)	lb.	....	1.50–1.65
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.65
Yellow	lb.	....	1.65
Sulphur (S)— Flowers, in bbls	Per 100 lb.	3.40	3.75–4.15
Flowers, in bags	Per 100 lb.	3.05	3.40–3.80
Flour, heavy, in 250 lb. bags	Per 100 lb.	2.95	3.30–3.70
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.15
Yellow orange	lb.	....	1.65

Polishing Materials

		Carlots	Less Carlots
Pumice Stone, American Ground FFF, FF, F	lb.	.04	.04½
0, 0½, ½, 1	lb.	.05	.05½
Putty Powder	lb.	Open price.	
Rotten Stone (Domestic)	lb.	.02¼	.03½
Rouge, Red	lb.	.18	.16
Black	lb.	.15	.18



for Anti-tank shells . . . or dehydrating foods

That tank-busting shell was hardened on a Wissco *Metal* Conveyor Belt. These modern conveyor belts are now speeding up heat treating and processing of both military and civilian goods.

Wissco Conveyor Belts are proving a new "find" for more and more industries. Typical wartime applications are hardening of projectiles and annealing shell cases; brazing; canning food; dehydration; rubber reclaiming, and tin salvaging.

Each Wissco belt is custom-engineered and manufactured to meet the requirements of a specific job, high or low temperature, chemical, abrasive or other kind of punishment. Back of each are 45 years of Wissco pioneering and accumulated experience.

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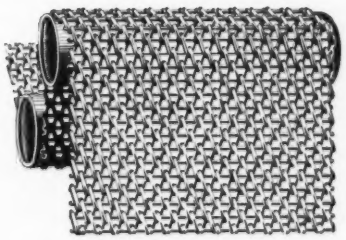

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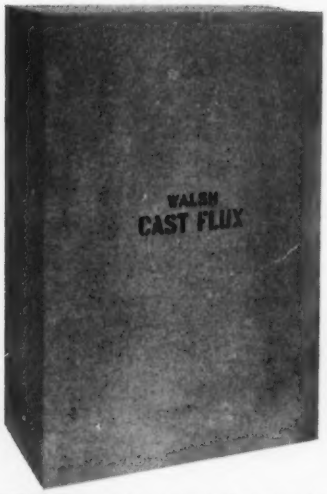

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ZINC OXIDES . . .
(*Continued from page 62*)

medium and the order of efficiency was Al—Zn—Ca—B—Mg—Ba—Pb, with alumina, zinc oxide and calcium oxide apparently superior and in the same order as in Fig. 4[a].

Unlike baryta 1—5 per cent zinc oxide was found to improve the resistivity towards water of the glasses investigated within the scope of the research project of Owens-Illinois quoted above[11]. Even the replacement of SiO_2 caused hardly any decrease of resistivity. The results can be seen from Fig. 9. Again Fe_2O_3 behaves similarly[13].

(e) Thermal Resistance, Mechanical and Thermal Properties

The practical successes of zinc containing glasses with respect to thermal shock suggest a favorable influence of zinc oxide on the following physical properties: strength, specific heat, thermal expansion.

The actual findings of research workers, especially of Gehlhoff and Thomas[12] are:

(1) The *tensile strength* is hardly changed by zinc oxide, but the *compression strength* is considerably increased. In the latter case replacement of alumina, magnesia, and even silica by zinc oxide was equally advantageous. *Hardness* is also improved by zinc oxide. *Elasticity* in the physical sense, that is response with a strong restoring force to external strain, is undesirable for thermal shock proof glass. Zinc oxide stands between barium oxide and silica in this respect[16], while the old Winkelmann Schott coefficient of elasticity would indicate that zinc oxide increases elasticity very much.

(2) The specific heat is decreased by zinc oxide more than by any oxide of the group:[12] ZnO, BaO, PbO, and very much more than by any other constituent. The conductivity is increased: zinc oxide, follows, quite significantly, silica, boric acid, magnesia, and alumina, while preceding the other divalent elements.

(3) The data on expansion vary with the base glass. The Winkelman coefficient of 1.8 would indicate high expansivity, while Turner's coefficient was characteristic of lower expansion.

In a previous paper[17] the possibility of zinc taking the position of silicon in the network of the glass structure proper had been discussed. The elements boron and aluminum are known to have this potential position and, depending on the actual position, a different expansion behavior is observed. The alkali content plays an important role inasmuch as it favors the network position of aluminum and boron, but maxima of concentration exist beyond which this position cannot be retained. The low expansion is connected with the structural position in the network. The conditions for the divalent zinc are certainly complicated and depend on the distribution of other constituents. Thus it is not surprising that some zinc glasses, for instance the alkali borosilicates and the pure borates, show low coefficients of expansion, while others have higher coefficients.

The possibility for zinc to proxy for silicon in the glass structure is certainly an important factor in the constitution of zinc glasses of advantageous properties. These properties are not the only indication of this possibility. The potential substitution of zinc for silicon has become probable on the basis of the following evidence:

(1) The small deviation in expansion observed in glasses where silicon was systematically replaced by zinc.[11]

(2) The series of efficiency in the mechanical properties as discussed before.

(3) The fourfold coordination of zinc in crystalline silicates, for instance, in willemite ($2\ ZnO.Sio_2$). The capacity of an ion to be satisfied with four instead of more oxygen neighbors is one of the requirements of an ion participating in the glass structure proper.

(4) The fact that this zinc orthosilicate can be obtained as a glass, while orthosilicates never can form glasses if the basic element does not participate in the glass structure[17].

(5) The small atomic polarization I observed in zinc phosphate glasses as compared to barium phosphate glasses. As a measure of atomic polarization the dielectric constant, which is depending on electronic plus atomic polarization, can be compared with the refractive index which depends on the electronic polarization only. (Fig. 10) With increasing zinc content the difference between the dielectric constant (k) and the square of the refractive index (n^2) decreases.

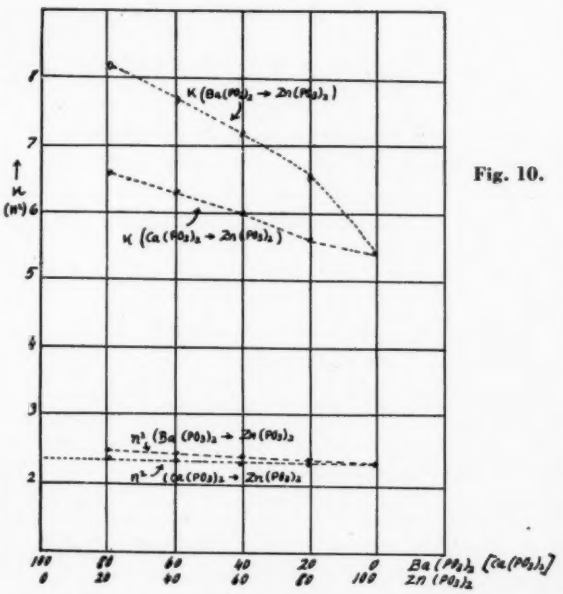

Fig. 10.

(6) Very recently E. Kordes[18] seems to have provided further evidence by the determination of densities and optical properties in the system $ZnO - P_2O_5$. This publication, however, is not available to the writer due to war conditions, except in the form of an abstract.

In fact, at the present time, the possibility of glass formers being partially substituted by elements of lower valency, will not meet as much prejudice as ten years ago, when the mentioning of MgO as an "amphoteric" oxide created some uneasiness[19]. At that time, the fourfold coordination of magnesium in various crystals was unknown. The thought that fourfold coordination, that is a surrounding by four oxygen ions, in a glass structure is the determining factor in properties formerly correlated with "acidity" has to be emphasized at the present time. In many cases both explanations work, but not in every one. A certain analogy between ZnO and Fe_2O_3

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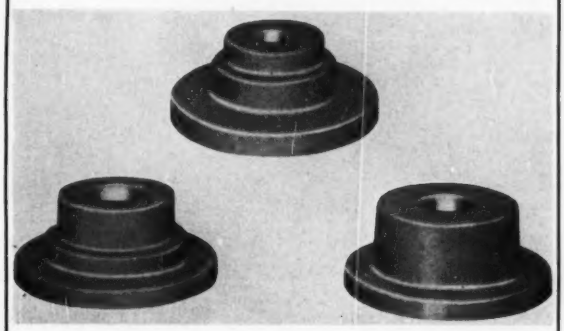

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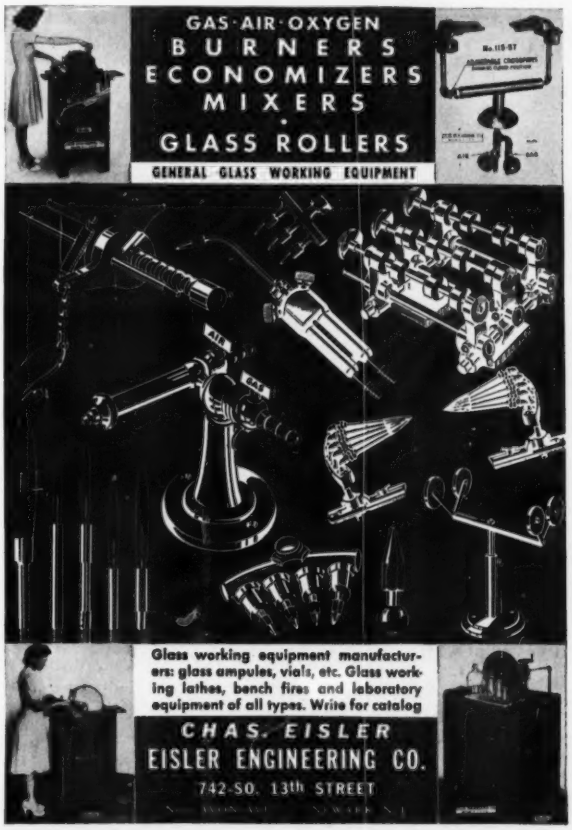
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with respect to viscosity and resistivity, as reported in the foregoing sections, can be understood by considering the ability of the Fe^{+++} ion to participate in the glass network proper, which is accentuated at high temperatures. An exact comparison would not be possible, because Fe_2O_3 and ZnO due to the difference of their actions, affect the oxygen arrangement of the glass in a different way.

(7) Further evidence can be gained from the observations of Linwood and Weyl[20] who studied the fluorescence of divalent manganese in base glasses of various structure.

In the high silica type of glass the divalent manganese exhibits a greenish fluorescence. The fluorescence is red in the looser structure of, for instance, high alkali glasses. Zinc silicate glasses were shown to be similar to pure SiO_2 in structure.

(8) Together with J. Freeman, I tested the influence of zinc oxide as compared with other divalent oxides on aluminum metaphosphate glasses. A sodium alumino-

TABLE IX

Fluorescence of Mn++ in Phosphate Glasses With Increasing ZnO Content

	A_1	A_2	A_3	A_4	A_5	A_6
Aluminum Metaphosphate	10	10	10	10	10	10
Sodium Metaphosphate	40	35	30	10	5	...
Zinc Metaphosphate	...	**5**	**10**	**30**	**35**	**40**
Manganese Carbonate	1	1	1	1	1	1
Cream of Tartar	.25	.25	.25	.25	.25	.25
Fluorescence Color	Deep red	red	red	orange	yellow orange	greenish yellow
Fluorescence Color if K replaces Na	red	reddish orange	orange	yellow orange	orange yellow	greenish yellow

phosphate glass exhibited the red manganese fluorescence of the type which was observed by Linwood and Weyl in alkaline glasses. The addition of increasing amounts of ZnO changed the fluorescence color to green, like in the case of the addition of SiO_2 in silicate glasses.

If in these glasses other divalent oxides are used in the place of zinc oxide, only magnesium oxide shows a slight resemblance to zinc oxide. Calcium, strontium, and barium behave more like the alkali and the fluorescence of the divalent manganese is red. Table X illustrates some examples.

This is again in accordance with the remarks made under (6) in this section on the slight relationship between magnesium and zinc as potential substitutes for silicon in the glass structure.

Similar experiments can also be performed with color indicators, especially cobalt and nickel.

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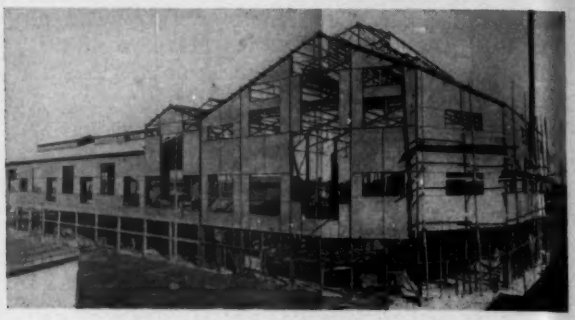

Factory Nearing Completion

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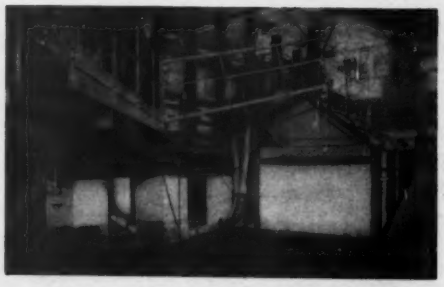
Charging End of Oil Fired Tank Furnace

Nose End of Tank Furnace Container Ware



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Published by
OGDEN PUBLISHING COMPANY 55 WEST 42ND STREET, NEW YORK, N. Y.
JOHN T. OGDEN, Publisher
CYRIL B. DELGADO, Editor and Business Manager
FLORENCE ASHLEY, Editorial Assistant
Pacific Coast Representatives: J. W. CONROW & CO., 1672 Walworth Ave., Pasadena, California

THE GLASS INDUSTRY, Vol. 24, No. 3, March, 1943. Published monthly by Ogden Publishing Company, at 55 West 42nd St., New York, N. Y. Subscription $3.00 a year. Canada, $3.50. Foreign, $4.00. Single copies 25 cents domestic, 35 cents Canada and foreign. Issues over three months old 50 cents. Entered as second class matter, August 10, 1921, at the Post Office at New York, N. Y., under act of March 3, 1879.

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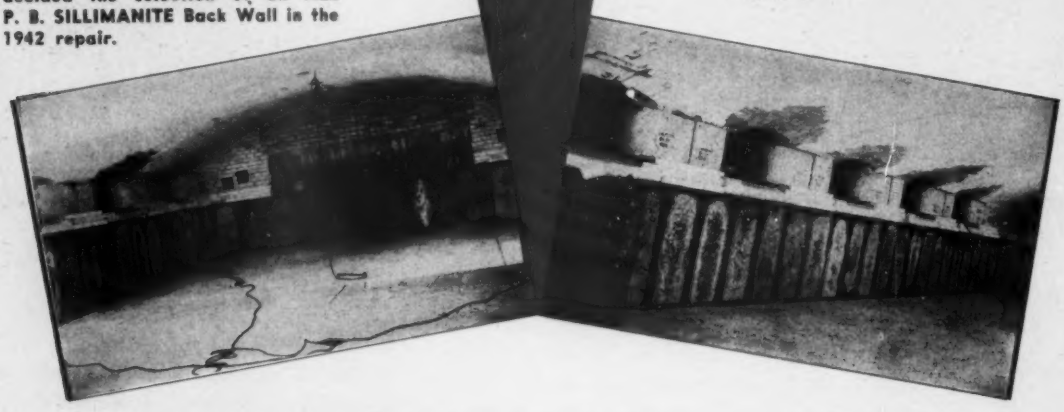

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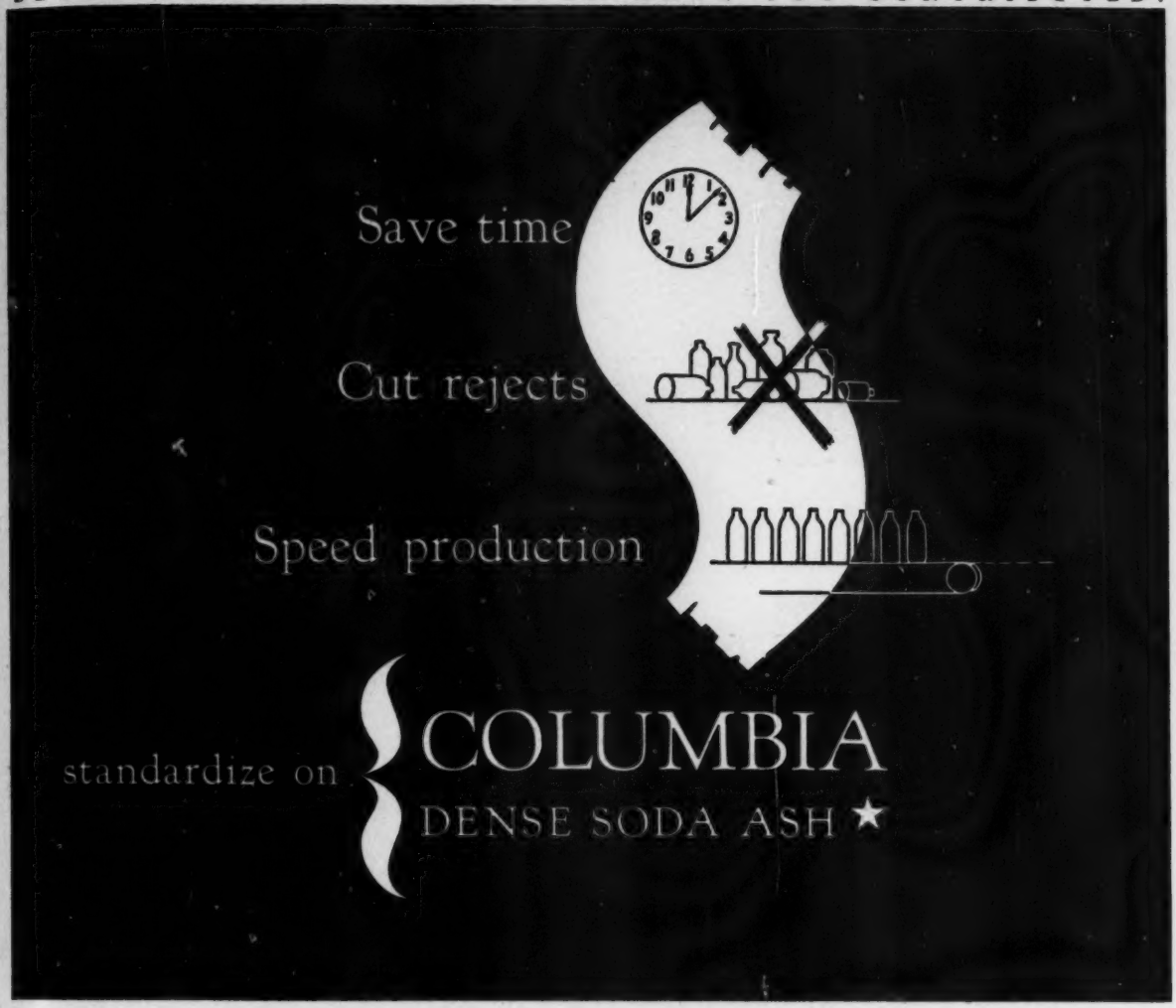

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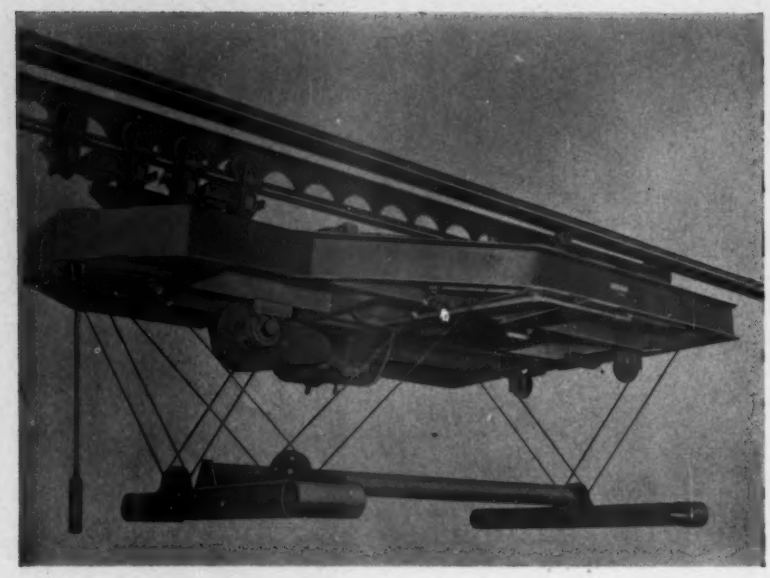

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The process is applied with the Metco Fuse-Bond Unit, operating on any 110 or 220 volt, single phase power line. This equipment fuses a rough deposit of electrode metal into the surface to be metallized. Electrodes are applied to the work with a special holder which uses up to six electrodes at a time.

The weight of the unit is 170 lbs. and is contained in a cabinet measuring only 24 inches high. All attachments fit into a bin in the top of the cabinet and it can be wheeled to the job on attached casters.

ELECTRONIC DRIVE

A new electronic variable speed drive has been introduced by General Electric which is ideally suited for many industrial applications because of the adjustable-voltage electronic control system, called Thy-mo-trol. This system in combination with a suitable motor provides a drive that has many features not usually found in other drives.

The standard drive of this type consists of an anode transformer, a control and rectifier panel, a push-button station and a d-c driving motor. The accelerating scheme, called constant-current limit acceleration, is capable of starting its load with a minimum of shock to the machine and will permit the motor to comutate satisfactorily.

Protection against sustained overload is provided by means of a conventional thermal overload relay, and the motor is stopped quickly by a dynamic breaking. Another feature of the Thy-mo-trol system is a "voltage-snubbing" circuit which automatically keeps the voltage down to a safe value. The motor speed-range has been tested and proved to operate over a range of up to 20 to 1 below base speed by armature control on an intermittent basis without exceeding a dangerous temperature rise.

Circuits have been so designed in the system that the equipment is entirely safe regardless of which tube or combination of tubes may fail. The equipment will either shut down instantly or will continue to operate.

CATALOGS RECEIVED

Leeds & Northrup Company, Philadelphia, Pa. Automatic control equipment for control of temperature, pH, conductivity or per cent SO_2 is the subject of a 29-page catalogue recently published by Leeds & Northrup. The equipment is explained in detail and extensive diagrams are included.

General Electric Company, Schenectady, N. Y., has published a booklet on "How Industrial Plants Can Increase Power Capacity." By installing their capacitors, the booklet states, plant circuits can carry more load with no increase in the total current demand.

Solvay Sales Corporation, New York, N. Y. A 30-page reference manual of Solvay products has just been put out by the Solvay Sales Corporation, giving specific information on forms and the chemical and physical properties of the products and their uses. In addition there are short chapters on safety methods.

General Electric Company, Schenectady, N. Y. The great scope of electronics is described with colorful words and illustrations in a new booklet issued by General Electric. Called "Electronics—A New Science for a New World," it shows pictorially the unbelievable present-day uses of the tiny electron and tells of the future possibilities of this particle of electricity.

Wheelco Instruments Co., Chicago, Illinois. Five new bulletins have just been released by Wheelco describing its complete line of industrial indicating, recording and control thermometers. The booklets are well illustrated.

ERNEST HOMMEL BURNED BY PLANT EXPLOSION

Ernest O. Hommel, president of the O. Hommel Company, is in the Pittsburgh Hospital recovering from burns on face and hands received from an explosion in his plant. The accident occurred on January 22 while Mr. Hommel was walking through the plant on an inspection trip. He and four others, who were also in the vicinity at the time, were taken to the hospital, and from last reports all of the injured were making a rapid recovery. The machinery damage has been repaired, and the department resumed its operations after three days' delay.

BALL BROTHERS ACQUIRE ARIDOR CO.

The Aridor Company, Chicago, Illinois, manufacturers of closures for glass containers, announce that ownership of the company is now held by Ball Brothers Company of Muncie, Indiana. The Aridor Company will continue to function as an independent unit in the manufacture and sale of caps. No change in management is contemplated; Colonel R. G. Peck remains as president and R. G. Peck, Jr., as vice-president and sales manager.

• Members of the American Forces stationed in Australia who are interested in glass have been cordially invited by Mr. T. C. Moorshead, Director of the United Glass Bottle Manufacturers, Ltd., at Bickley, Kent, to visit any of their factories, according to a letter received by Francis C. Flint of the Hazel-Atlas Glass Company.

Help Wanted . . .

Required April 1st several Continuous Glass Tank Teasers.

Required April 1st several Tube Drawing Mandrel Furnace Operators.

Required At Once. Analytical Chemist for silica analysis in modern Glass Plant.

Required At Once. One Technician for Glass Plant Control Laboratory work. Required: Several machine mechanics for maintaining work. Must be familiar with glass making machinery.

Continuous Glass Operating Plant with Day Tanks requires the services of one foreman familiar with furnace operation and two Tube Drawing Room foremen.

Address replies to Box 55
THE GLASS INDUSTRY
55 West 42nd Street, New York, N. Y.

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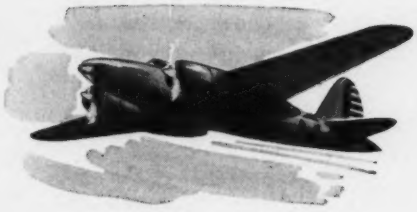

The new *magnesium metal*, made from dolomite limestone, is contributing to the production of essential war needs.

The combined qualities of lightness, strength and durability make magnesium metal desirable for the metal skin of warplanes, castings for cylinders, pistons and other parts.

Today, most of the entire output of the Banner Quarries is going into essential war production . . . STEEL, AGRICULTURE, BUILDING and GLASS . . . and now Banner contributes to the production of another number one War Essential . . . MAGNESIUM METAL.

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Grant Building, Pittsburgh, Pa.
Since 1907 . . . A good company to do business with

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	50.00	55.00
Precipitated material		55.00	60.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o b. shipping point	ton	15.00–16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)			
Granulated	In bulk, ton	42.50	....
Granulated	In bags, ton	46.00	56.00–61.00
Powdered	In bags, ton	51.00	61.00–66.00
Boric acid (H_3BO_3)			
Granulated	In bulk, ton	96.50	
Granulated	In bags, ton	100.00	111.00–116.00
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.09½–.09¾	.10
Synthetic (Artificial)	lb.	No supplies available.	
Feldspar—(published list prices)			
20 mesh	ton	11.00–13.25	
40 mesh	ton	11.50–13.75	
Granular	ton	11.75–14.00	
Semi-granular	ton	11.00–13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags.			
Fluorspar (CaF_2) domestic, ground, 96–98% (max. SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	34.00	....
In bags	ton	36.40	50.00
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.0900	....
In 5 Ton lots	lb.	....	.0950
Less than 5 Tons	lb.	....	.10
Lime—			
Hydrated($Ca(OH)_2$–MgO) (in paper sacks)	ton	8.50	9.50
Burnt (CaO–MgO) ground, in bulk	ton	7.50	....
Burnt, ground, in paper sacks	ton	9.50	9.50
Burnt, ground, in 191 lb. gross drums Per drum		1.70	1.80
Kiln Dried ($CaCO_3$–$MgCO_3$) 10x30 mesh	ton	2.00	....
Kiln Dried ($CaCO_3$–$MgCO_3$) 16x120 mesh	ton	2.00	....
Nepheline Syenite, f. o. b. shipping point	In bulk, ton	12.00	15.00
Potassium carbonate—			
Calcined (K_2CO_3) 96–98%	lb.	.065	.0675
Hydrated 80–85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4) in bags	ton	21.00–22.00	28.00 30.00
in bulk		17.50	
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In Paper bags	Per 100 lb.	1.10	
In Burlap bags	Per 100 lb.	1.15	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls	Per 100 lb.	....	3.00–3.40
95% and 97%			
Bulk	Per 100 lb.	1.35	2.50–3.00
200 lb. bags		1.4675	....
100 lb. bags		1.5025	....

Special Materials

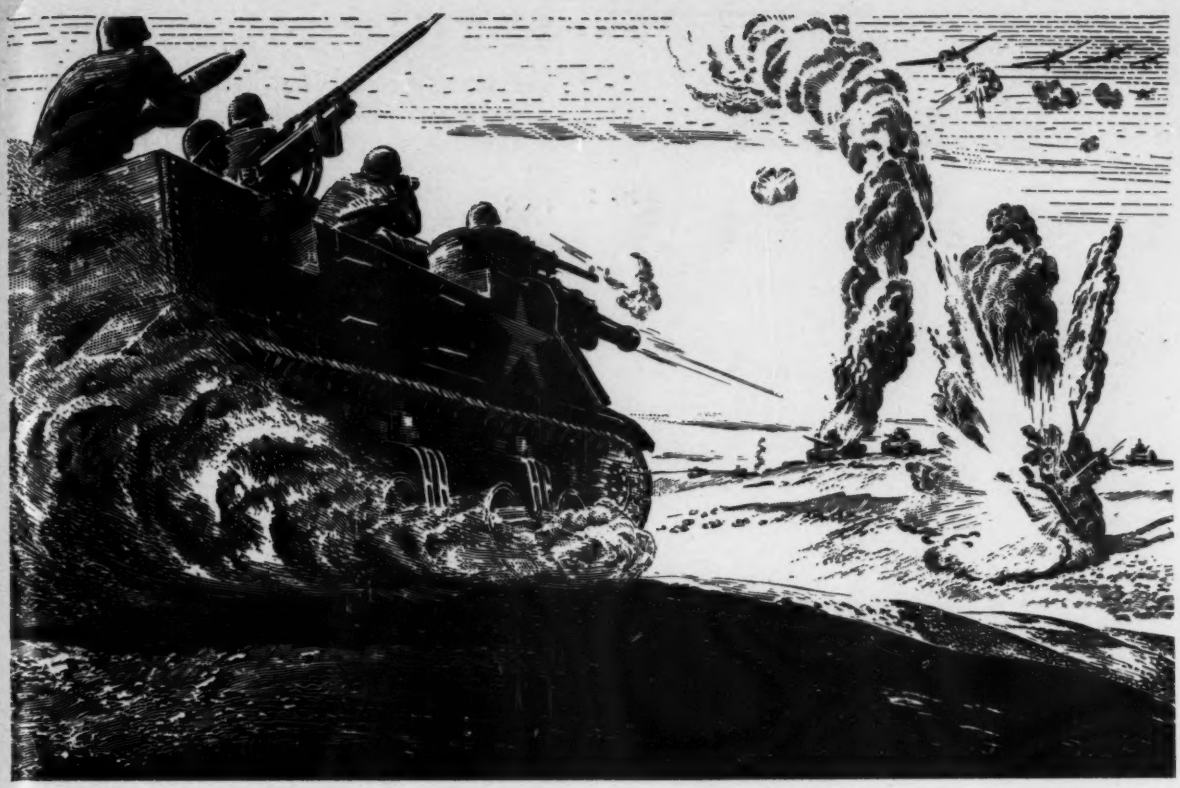
		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	.031–.034	.045
Aluminum oxide (Al_2O_3)		.07	.09
Antimony oxide (Sb_2O_3)	lb.	Open price	.15½–.17½
Arsenic			
Glassmakers	lb.	.04¼	.04¾
Regular refined white	lb.	.04	.04½
Arsenic trioxide (As_2O_3) (dense white) 99%			
In barrels		.04–.04¼	.04½–.04¾
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	Open price.
Pyrophyllite (20% Al_2O_3)	ton	10.00	13.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.05	.06–.06½
Tin Oxide (SnO_2) in bbls	lb.	....	Open price.
Titanium Oxide (ceramic grade)			
In bags	lb.	.14½	....
In barrels	lb.	.14¾	....
Zinc Oxide (ZnO)			
American process, bags	lb.	.07¼	.07½
White Seal, 150 lb. bbls	lb.	.09¾	.10
Green Seal, bags	lb.	.09	.09¼
Domestic White Seal, bags	lb.	.09½	.09¾
Red Seal, bags	lb.	.08½	.08¾
Zircon			
Refined Granular (Milled .01–.02c higher)		.03½	.04¼

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40–1.60
(Commercial, 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	1.10–1.15
Cerium hydrate—			
600 lb. barrels	lb.	....	.65
Chrome Oxide Green, 400 lb. bbls	lb.	....	.25–.28
Chromite (99% through 200 mesh)	ton	58.25	64.75
Chromite ore (air floated)	ton	58.25	64.75
Cobalt oxide (Co_2O_3)			
In bbls. 350 lbs. or more,	lb.	....	1.84
Less than 350 lbs.,	lb.	....	1.94
Copper oxide—			
Red (Cu_2O)	lb.	....	.20–.22
Black (CuO)	lb.	....	.19–.22½
Black prepared	lb.	....	Open price.
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.06½–.10
Black (Fe_3O_4)	lb.	....	....
Iron Chromate	lb.	....	.035–.05
Lead Chromate ($PbCrO_4$) in bbls	lb.	....	.16
Lithium Carbonate	lb.	....	1.25
Manganese, Black Oxide African			
In Paper bags	ton	70.00	78.00
In Burlap bags	ton	71.75	79.75
In Casks	ton	74.00	82.00
Neodymium oxalate, 50 lb. drums	lb.	....	4.00
Nickel oxide (Ni_2O_3), black	lb.	....	.34–.40
Nickel monoxide (NiO), green	lb.	....	.35–.37
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals and Granular	lb.	.09¼	.09¾–.10
Powdered	lb.	....	.10¼–.10½
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.21–.25
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) in 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.07¼	.07½–.07¾
Sodium chromate (Na_2CrO_7) Anhydrous	lb.	.08⅜	.08⅞–.09¼
Sodium selenite (Na_2SeO_3)	lb.	....	1.50–1.65
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.65
Yellow	lb.	....	1.65
Sulphur (S)—			
Flowers, in bbls	Per 100 lb.	3.40	3.75–4.15
Flowers, in bags	Per 100 lb.	3.05	3.40–3.80
Flour, heavy, in 250 lb. bags	Per 100 lb.	2.95	3.30–3.70
Uranium oxide (UO_2) (black, 96% U_3O_8)			
100 lb. lots. Black	lb.	....	2.15
Yellow orange	lb.	....	1.65

Polishing Materials

		Carlots	Less Carlots
Pumice Stone,			
American Ground FFF, FF, F	lb.	.04	.04½
0, 0½, ½, 1	lb.	.05	.05½
Putty Powder	lb.	Open price.	
Rotten Stone (Domestic)	lb.	.02¼	.03½
Rouge, Red	lb.	.18	.16
Black	lb.	.15	.18



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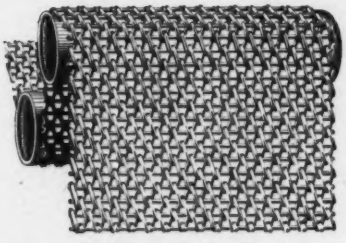
That tank-busting shell was hardened on a Wissco *Metal* Conveyor Belt. These modern conveyor belts are now speeding up heat treating and processing of both military and civilian goods.

Wissco Conveyor Belts are proving a new "find" for more and more industries. Typical wartime applications are hardening of projectiles and annealing shell cases; brazing; canning food; dehydration; rubber reclaiming, and tin salvaging.

Each Wissco belt is custom-engineered and manufactured to meet the requirements of a specific job, high or low temperature, chemical, abrasive or other kind of punishment. Back of each are 45 years of Wissco pioneering and accumulated experience.

Write for free book, "Wissco Metal Conveyor Belts." Wickwire Spencer Steel Co., 500 Fifth Avenue, New York, or Buffalo, Chicago, Worcester, San Francisco.



FLEXIBILITY? Wissco Conveyor Belt construction permits operation over small diameter pulleys, insuring extreme flexibility and economy in design.

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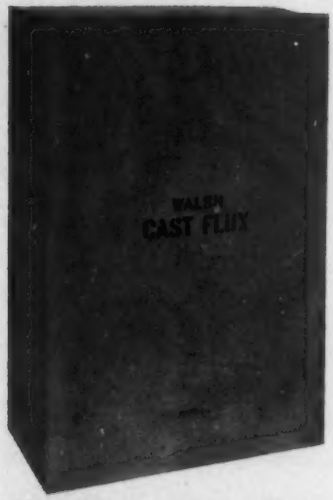


The Vacuum-cast flux block of superior quality.

Walsh Cast-Flux blocks are machine-trued to exact size and shape after burning.

THEY LAST LONGER

The excellent results obtained in numerous tanks melting various types of glass has definitely established the efficiency and economy of Walsh Cast-Flux blocks.

Walsh Cast-Flux has a dense, uniform structure; it is burned at higher temperatures, is thoroughly bonded and possesses a low coefficient of expansion.

Walsh Cast-Flux blocks meet the most rigid requirements for tanks operating at higher temperatures . . . they insure greater tonnage, higher quality glass, freedom from defects, longer life and maximum economy.

WALSH REFRACTORIES CORPORATION

Manufacturers of Refractories for the glass industry for over 50 years

4428 North First Street
St. Louis Missouri

ZINC OXIDES . . .
(*Continued from page* 62)

medium and the order of efficiency was Al—Zn—Ca—B—Mg—Ba—Pb, with alumina, zinc oxide and calcium oxide apparently superior and in the same order as in Fig. 4[a].

Unlike baryta 1—5 per cent zinc oxide was found to improve the resistivity towards water of the glasses investigated within the scope of the research project of Owens-Illinois quoted above[11]. Even the replacement of SiO_2 caused hardly any decrease of resistivity. The results can be seen from Fig. 9. Again Fe_2O_3 behaves similarly[13].

(e) Thermal Resistance, Mechanical and Thermal Properties

The practical successes of zinc containing glasses with respect to thermal shock suggest a favorable influence of zinc oxide on the following physical properties: strength, specific heat, thermal expansion.

The actual findings of research workers, especially of Gehlhoff and Thomas[12] are:

(1) The *tensile strength* is hardly changed by zinc oxide, but the *compression strength* is considerably increased. In the latter case replacement of alumina, magnesia, and even silica by zinc oxide was equally advantageous. *Hardness* is also improved by zinc oxide. *Elasticity* in the physical sense, that is response with a strong restoring force to external strain, is undesirable for thermal shock proof glass. Zinc oxide stands between barium oxide and silica in this respect[16], while the old Winkelmann Schott coefficient of elasticity would indicate that zinc oxide increases elasticity very much.

(2) The specific heat is decreased by zinc oxide more than by any oxide of the group:[12] ZnO, BaO, PbO, and very much more than by any other constituent. The conductivity is increased: zinc oxide, follows, quite significantly, silica, boric acid, magnesia, and alumina, while preceding the other divalent elements.

(3) The data on expansion vary with the base glass. The Winkelman coefficient of 1.8 would indicate high expansivity, while Turner's coefficient was characteristic of lower expansion.

In a previous paper[17] the possibility of zinc taking the position of silicon in the network of the glass structure proper had been discussed. The elements boron and aluminum are known to have this potential position and, depending on the actual position, a different expansion behavior is observed. The alkali content plays an important role inasmuch as it favors the network position of aluminum and boron, but maxima of concentration exist beyond which this position cannot be retained. The low expansion is connected with the structural position in the network. The conditions for the divalent zinc are certainly complicated and depend on the distribution of other constituents. Thus it is not surprising that some zinc glasses, for instance the alkali borosilicates and the pure borates, show low coefficients of expansion, while others have higher coefficients.

The possibility for zinc to proxy for silicon in the glass structure is certainly an important factor in the constitution of zinc glasses of advantageous properties. These properties are not the only indication of this possibility. The potential substitution of zinc for silicon has become probable on the basis of the following evidence:

(1) The small deviation in expansion observed in glasses where silicon was systematically replaced by zinc.[11]

(2) The series of efficiency in the mechanical properties as discussed before.

(3) The fourfold coordination of zinc in crystalline silicates, for instance, in willemite (2 $ZnO.Sio_2$). The capacity of an ion to be satisfied with four instead of more oxygen neighbors is one of the requirements of an ion participating in the glass structure proper.

(4) The fact that this zinc orthosilicate can be obtained as a glass, while orthosilicates never can form glasses if the basic element does not participate in the glass structure[17].

(5) The small atomic polarization I observed in zinc phosphate glasses as compared to barium phosphate glasses. As a measure of atomic polarization the dielectric constant, which is depending on electronic plus atomic polarization, can be compared with the refractive index which depends on the electronic polarization only. (Fig. 10) With increasing zinc content the difference between the dielectric constant (k) and the square of the refractive index (n^2) decreases.

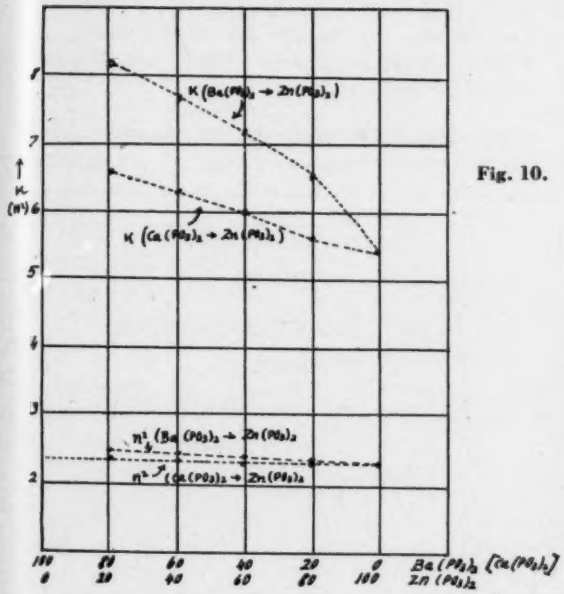
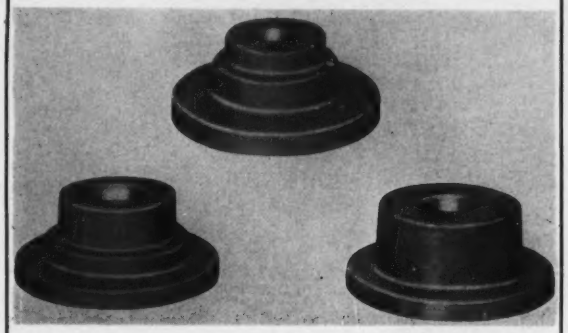


Fig. 10.

(6) Very recently E. Kordes[18] seems to have provided further evidence by the determination of densities and optical properties in the system $ZnO - P_2O_5$. This publication, however, is not available to the writer due to war conditions, except in the form of an abstract.

In fact, at the present time, the possibility of glass formers being partially substituted by elements of lower valency, will not meet as much prejudice as ten years ago, when the mentioning of MgO as an "amphoteric" oxide created some uneasiness[19]. At that time, the fourfold coordination of magnesium in various crystals was unknown. The thought that fourfold coordination, that is a surrounding by four oxygen ions, in a glass structure is the determining factor in properties formerly correlated with "acidity" has to be emphasized at the present time. In many cases both explanations work, but not in every one. A certain analogy between ZnO and Fe_2O_3

Gunite's Standard grade A
for
Guide Rings



Like all Gunite glasshouse castings Standard grade A is used for guide rings because it is best adapted to this particular purpose.

There is a suitable Gunite Alloy for every type of glass mould part requirement. Miller plungers and guide rings, neck ring sticks, brushing stock, press and blow moulds.

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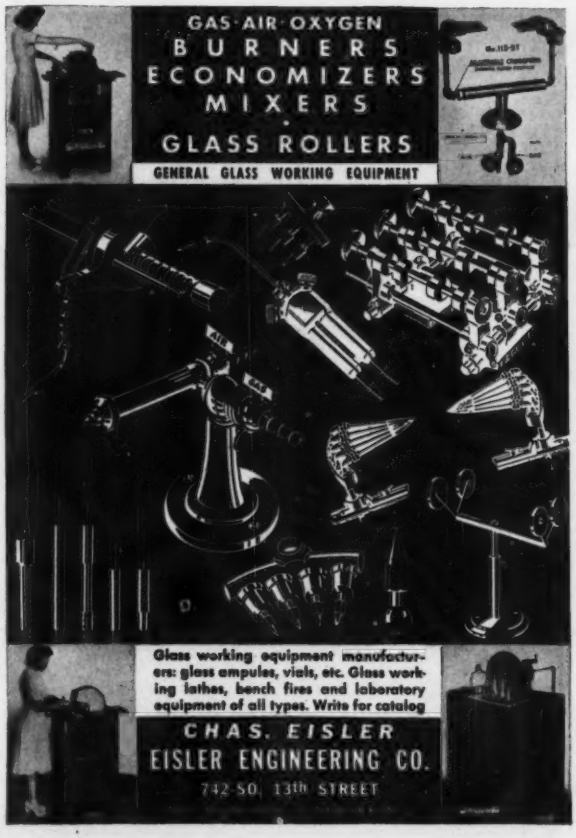
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The World's Largest Producers of Glass House Refractories
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with respect to viscosity and resistivity, as reported in the foregoing sections, can be understood by considering the ability of the Fe^{+++} ion to participate in the glass network proper, which is accentuated at high temperatures. An exact comparison would not be possible, because Fe_2O_3 and ZnO due to the difference of their actions, affect the oxygen arrangement of the glass in a different way.

(7) Further evidence can be gained from the observations of Linwood and Weyl[20] who studied the fluorescence of divalent manganese in base glasses of various structure.

In the high silica type of glass the divalent manganese exhibits a greenish fluorescence. The fluorescence is red in the looser structure of, for instance, high alkali glasses. Zinc silicate glasses were shown to be similar to pure SiO_2 in structure.

(8) Together with J. Freeman, I tested the influence of zinc oxide as compared with other divalent oxides on aluminum metaphosphate glasses. A sodium alumino-

TABLE IX

Fluorescence of Mn++ in Phosphate Glasses With Increasing ZnO Content

	A_1	A_2	A_3	A_4	A_5	A_6
Aluminum Metaphosphate	10	10	10	10	10	10
Sodium Metaphosphate	40	35	30	10	5	...
Zinc Metaphosphate	...	**5**	**10**	**30**	**35**	**40**
Manganese Carbonate	1	1	1	1	1	1
Cream of Tartar	.25	.25	.25	.25	.25	.25
Fluorescence Color	Deep red	red	red	orange	yellow orange	greenish yellow
Fluorescence Color if K replaces Na	red	reddish orange	orange	yellow orange	orange yellow	greenish yellow

phosphate glass exhibited the red manganese fluorescence of the type which was observed by Linwood and Weyl in alkaline glasses. The addition of increasing amounts of ZnO changed the fluorescence color to green, like in the case of the addition of SiO_2 in silicate glasses.

If in these glasses other divalent oxides are used in the place of zinc oxide, only magnesium oxide shows a slight resemblance to zinc oxide. Calcium, strontium, and barium behave more like the alkali and the fluorescence of the divalent manganese is red. Table X illustrates some examples.

This is again in accordance with the remarks made under (6) in this section on the slight relationship between magnesium and zinc as potential substitutes for silicon in the glass structure.

Similar experiments can also be performed with color indicators, especially cobalt and nickel.

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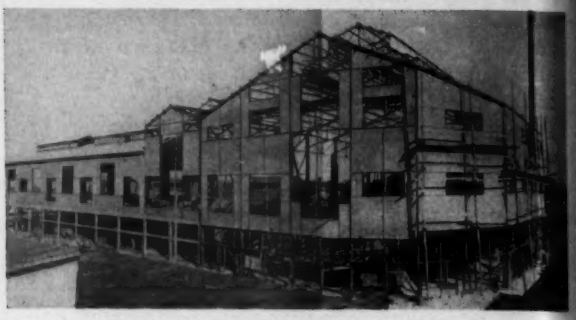

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